University of Alberta

The Effects of Weaning on Cow Calf Production Efficiency and Cattle Production Economics

by

Christoph Eusebio Weder ©

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ABSTRACT: Over a three-year period 240 spring-calving cows (mean ± SD: age 5.9±0.04 years, body weight (BW) 605±8 kg; body condition score (BCS) 2.6±0.06 (scale 1-5); calving date: (May 1±12d) were used to compare very early (VEW: 72±12 d) with early (EW: 132±12 d), and normal weaning (NW: 192±12 d) on cow and calf performance. Heifer calves were backgrounded on pasture and steers split between pasture (VEWP, EWP) and feedlot (VEWF, EWF) until the time of NW. After NW all calves were moved into feedlot. From the time of parturition cow BCS and BW increased as weaning age decreased ($P<0.05$). Two out of the three years VEW and EW cows had significantly ($P<0.05$) greater BCS and BW than NW cows. Conception rates, calving intervals and calf birth weights were similar ($P>0.05$) for all treatments; but culling rates were lowest ($P<0.05$) for VEW. Heifer ADG from VEW to the time of NW were lower ($P<0.05$) for VEW heifers (0.8 kg/d) and marginally ($P<0.10$) lower for EW heifers (0.9 kg/d) than for NW heifers (1.0 kg/d). Through the backgrounding period treatment differences in ADG for heifers were negligible ($P>0.05$). Results for cyclicity pooled over years (74% of VEW, 85% of EW and 95% of NW cycling at 13 months of age) suggested that weaning treatment had an effect on sexual maturity. Steer ADG from July 9th to Sept. 9th was lowest ($P<0.05$) for VEWP (0.9 kg/d); intermediate for VEWF and EWP (1.1 kg/d) and greatest for EWF and NW (1.2 kg/d). ADG in the feedlot was not affected by treatment ($P>0.05$), however from birth to slaughter the VEWP steers had lower ADG ($P<0.05$) than the EWP, EWF and NW steers, while VEWF steers were intermediate. Days on feed and carcass traits for quality and yield grades were not affected by weaning treatment. Carcass weight, ribeye area (REA) and back fat depth were lower for VEWP and VEWF ($P<0.05$) compared to the EWP, EWF and NW steers.

When REA was expressed as a ratio with carcass weight, there were no differences (P>0.05) among treatments. Feed to gain ration was greatest for VEWP (6.7:1); intermediate for VEWF and EWF (6.3 and 6.4:1) and least for EWP and NW (6.0 and 6.1:1). Net income for the cow/calf systems indicated that EW and backgrounding the calves on pasture until Nov. 9th generated the most net income.

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The two thoughts that always kept me going and that I live by:

#1) Principals are applied with judgment and rules are administered for minimal need for thought and #2) turn goals into results.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
AAFRD	Alberta Agriculture Food and Rural Development
ADG	average daily gain
AMPT	alpha-methylparatyearosine
BW	body weight
BC	body condition
BCS	body condition score
cAMP	cyclic adenosine monophospate
^oC	degrees Celsius
d	day
EW	early wean
GH	growth hormone
GnRH	gonadotropin releasing hormone
IGF-1	insulin-like growth factor-1
kg	kilogram
LH	leutensing hormone
LW	late wean
NE	net energy
NW	normal wean
ME	metabolizable energy
PPI	post partum Interval
REA	ribeye area

SNS	sympathetic nervous system
ST	somatotropin
VEW	very early wean
VFA	volatile fatty acids
wk	week

CHAPTER 1

A REVIEW OF METABOLIC AND ENDOCRINOLOGICAL SYSTEMS GOVERNING COW BODY WEIGHT AND BODY CONDITION IN LACTATING BEEF CATTLE

1.1 Introduction

The Western Canadian beef industry has faced and will continue to face many challenges. Unlike the dairy and poultry industries, the cow/calf industry does not have control over markets and is a price taker. From the examples of price reductions for beef cattle, as documented through the BSE border closures, to increases in input costs like fuel and fertilizer, and a rise in the value of the Canadian dollar, which decreases export demands; all have combined to erode the net returns to cow /calf producers. These facts emphasize that for the cow/calf industry to remain profitable it has to be a low cost provider and a high valued marketer (Christensen, 2003).

Shifting weaning dates has been suggested as a way of improving herd performance (Lusby et al. 1981; Whittier, 1995; Story et al. 2000) and subsequent economic returns. An increase in profit potential may be realized by greater herd reproductive performance, reduced winter feed costs and possibly, alternative calf marketing options. In most beef herds, calves are born over a period of several weeks to months, but traditionally all the calves are weaned on the same day at six to eight months of age (AAFRD, 1998). This type of weaning management may suit many cow/calf operations. However there can be many factors such as drought and high feed costs that can undermine the management efforts to wean calves at six to eight months of age.

Another example is the increased cost associated with the winter feeding of cows that have low body condition scores. Many researchers (Lusby et al.1991; Myers et al. 1999a; Story et al. 2000) have studied the effect of altered weaning dates on the cow and calf, there is however limited research that has looked at weaning as a management tool under retained ownership. Furthermore, very few studies have examined weaning management and its economic implications to the cow calf production system.

This thesis will first review metabolic and endocrinological systems that govern cow body weight and body condition in lactating beef cattle. Then a literature review of previous research on weaning and its effects on the calf will be presented.

The objective of the research in this thesis was to evaluate the biological and economic effects of three weaning treatments; Very Early Wean (VEW; 72 d), Early Wean (EW; 132 d) and Normal Wean (NW; 192 d) on the cow and calf. Following the review of the biological experiment a review of economic factors affected by weaning will be discussed along with methods with which they can be analyzed. Using the data from the weaning experiment, an economic evaluation and comparison of the weaning treatments was done using enterprise budgeting and breakeven analysis. Finally, in the last chapter a comparison of weaning treatments is presented using economic variables that would be typical of a Low Feed Cost (LFC) and High Feed Cost (HFC) year.

The hypothesis for this research was that biological and economic outcomes from very early weaning (VEW; 72d) and early weaning (EW; 132d) and normal weaning (NW; 192d), would not differ for both cows and calves.

1.2 General background on beef herd management

According to Statistics Canada (2005), there are approximately 5.5 million beef cows in Canada, of which 2.25 million are in Alberta. These animals are maintained under a variety of management and environmental conditions and wean an annual calf crop estimated at 80% from cows exposed during the breeding season (AAFRD 1998). Data reported in the last beef cow/calf audit (AAFRD 1998) suggest first cycle conception was less than 48%. The main contributing factor to this statistic may be the fact that less than 55% of replacement heifers and 40% of thin cows are fed separately from the mature cow herd. Complicating matters further, only 25% of Alberta cow/calf producers condition score their cows (AAFRD 1998). Cows and heifers with low body condition scores (BCS < 2.0; scale 1-5 where 1 is emaciated and 5 is grossly obese) at calving have long been documented as having longer post partum intervals than cows or heifers with good (BCS>2.0) body condition scores (Lamond 1970; Short et al. 1990)

If Canadian producers could achieve a 90% calf crop, they could market an additional 475 thousand calves per year from the same sized cowherd. A 10% increase in production efficiency to the Alberta and Canadian beef industry would represent a huge economic improvement. There are a number of reasons for the overall 20% shortfall in potential calf crop. The first 10% loss can be related to factors such as calving difficulty and post-calving calf mortality through diseases like scours and pneumonia. The contributing factor for the other 10% shortfall is poor reproductive performance of the cow herd. There is a lack of body condition score management; cows that have low body condition scores at the point of calving have reduced cyclicity, which contributes to poor conception rates within the cowherd (Paterson 2002).

Postpartum nutrition with respect to rebreeding has long been recognized as an important factor influencing cow conception rates (Short et al. 1990). The majority of reproductive shortfalls in the beef industry are attributed to under-nutrition due to feed shortages, poor-quality feeds and (or) management. Many of the findings and reviews of under-nutrition affects on reproduction point to an extension from calving to the first postpartum estrus, which is commonly referred to as the postpartum interval (PPI). The economic implications to beef producers of an increased PPI on the following year's calf crop can vary. First, there will be reduced weaning weights if the weaning date is held consistent with the previous year. Second the producer can experience increased supplemental feed costs and increased cow open rates due to an increase in the length of the calving season and the inability for certain cows to breed back within the set breeding season. Cow body weight (BW) and body condition (BC) have long been recognized as having enormous effects on the length of PPI. Understanding how these two factors influence conception is key, if there are to be improvements within the Canadian beef industry.

1.3 Reproductive controls: cow body weight and body condition

Although it is difficult to ascertain if specific nutrients limit reproduction through common or discrete mechanisms, appropriate quantities of the nutrients are required for optimal reproduction (Dunn and Moss, 1992). Under practical conditions, much of the variation in reproductive performance of beef cows may be accounted for by differences in energy intake and body condition (Hess et al. 2005). The concept of a target BW and

BC at the time of calving was first proposed by Lamond (1970). Whitman (1975) found that cows calving at body condition scores (BCS) of 3.5 to 4.5 (range of 1 to 5) were capable of returning to estrus within 60 days of parturition regardless of pre- or postpartum change in BW. Reviews of the scientific literature published within the last 15 yr demonstrated 1) prepartum nutrition is more important than postpartum nutrition in determining the length of postpartum anestrus; 2) inadequate dietary energy during late pregnancy lowers reproduction even when dietary energy is sufficient during lactation; 3) a BCS ≥3 (scale 1-5; 1 emaciated and 5 is grossly obese) will ensure body reserves are adequate for postpartum reproduction; and 4) further declines in reproduction occur when lactating beef cows are in negative energy balance (Randel 1990; Short et al. 1990; Williams 1990; Dunn and Moss 1992; Hess et al. 2005). The regression analyses conducted by Dunn and Kaltenbach (1980), and later refined by Short et al. (1990), clearly established the relationship between plane of nutrition x BCS and reproduction of beef cows. These authors indicate that this minimum BC will ensure that body stores of nutrients are adequate for postpartum reproductive performance. In fact, recent findings by Lalman et al. (2000) found that post-calving energy supplementation only served to enhance milk production in primiparous heifers and that precalving BC had a greater influence on PPI than post calving energy levels. Contrary to this research, Boadi and Price (1993) concluded that pre and early postnatal feed restriction on multiparous beef cows did not affect PPI and reproductive performance. Explanations for the differences in results may be the fact that the cows in Boadi and Prices (1993) experiment never calved below a body condition score of 2.5 (1-5 scale), which other researchers (Lamond 1970; Whitman 1975) documented as the target BCS at calving.

Relationships between energy intake and BC in terms of reproductive success have been well documented (Bauman and Currie 1980; Short et al. 1990). These observations have stimulated many research trials studying the relationship between nutrient intake and body fatness and the subsequent effects on reproductive variables (Bellows et al. 1974; Short and Adams 1988). Dietary restrictions during late pregnancy that results in BW and BC reductions, increase the time interval needed for cows and first-calf heifers to return to estrus (Whitman 1975; Deziuk and Bellows 1983). Similar results have been reported when dietary restrictions occur during the postpartum period (Richards et al. 1986). Regression equations relating energy status, as expressed by BW change, against reproductive performance were developed by Dunn and Kaltenbach (1980) from data published by a number of researchers. They also developed regression equations by taking the average length of the PPI and comparing it to the average prepartum BW change. When no prepartum weight losses occurred, 91% of multiparous and 64% of primiparous cows would be predicted to be in estrus by 60 days postpartum.

So why does body condition have such a profound effect on reproductive success? One theory that has remained popular is that there is a "set point" of body fat or body composition, above or below which the adipose mass signals the central nervous system, that the body is either ready or not for cycling and pregnancy (Frisch 1980). Research has demonstrated that there is a relationship between body fat and reproductive efficiency, however, there have been many reports where body fat content was negative, yet cycling was still positive (Dunn and Kaltenbach 1980; Deziuk and Bellows 1983). There was a theory that estrogen release from adipose tissue was the controlling factor behind reproduction (Frisch 1980; Wade and Schneider 1992).

Weaning has also been the focus in many research trials as a management tool to manipulate BC and BW. In Australia research on early weaning strategies for emergency drought management showed that there are significant advantages in improving BC, reducing lactation stress and increasing reproductive rates by manipulating the timing of weaning (Schlink et al. 1988; McSweeny et al. 1993a, 1993b). In more extensive studies, the practice of "Early Weaning" has dramatically reduced dry season BW and BC loss and increased pregnancy rates (Schlink et al. 1988, 1994; Sullivan et al. 1992). In North America, Bellows and Short (1974) found that early weaning (120 days) primiparous heifers in poor BC significantly ($P<0.01$) improved BC and shortened the PPI compared to normal weaned heifers (205 days).

Early weaning has also shown significant advantages as a management tool for mature cows. Even under pasture situations, there are times when the nutrients supplied are insufficient to maintain milk production as well as sustain adequate BW and BC of the dam (Short and Adams 1988). When this scenario exists, early weaning may yield considerable advantages as a management tool (Richardson et al 1978; Lusby et al. 1981). The biological cost of lactation in a 600 kg cow, producing 10 kg milk / day, represents a 33% increase over maintenance in energy requirements and a 40% increase in protein requirements (NRC 1996).

Most research agrees that ovulation is controlled by the release of leutensing hormone (LH), which in turn, is regulated by gonadotropin releasing hormone (GnRH), which are themselves related to body composition (Villa-Godoy et al. 1988; Wade and Schneider 1992; Rozeboom et al. 1993). In Australia researchers found that a lean BC (BCS < 1.5; scale 1- 5) at calving was associated with prolonged post-partum anoestrous intervals in suckled cows (Jolly et al. 1993). So is reproductive cyclicity related strictly to body composition and condition or are there other biochemical mechanisms that have influence?

1.4 Reproductive controls: blood metabolites

The measurement of blood metabolites may be another useful indicator of nutritional status and potential rebreeding performance. The relationship between increased growth hormone (GH) and decreased insulin during early lactation suggests a role of metabolic hormones in promoting mobilization of adipose tissue stores to fulfill energy needs (Randel 1990; Hess et al. 2005). An increasing focus has been given to free glucose within the animal as a main indicator of reproductive success (Short and Adams 1988; McNamara 1995). It appears that serum GnRH and LH concentrations are related to glucose availability, which may not be related at all to BC. Wade and Schneider (1992) showed that there was a large release of GnRH and LH following an increase in energy in the diet of restricted hogs. Short and Adams (1988) demonstrated that the release of GnRH and LH, and thus ovulatory activity, is affected by glucose supply. This would seem because glucose is the only energy source utilized by the neural system and given that the neural-endocrine system is intimately involved in the control of reproduction and hormone secretion, blood glucose concentration would be the specific mediator for the effects of energy intake on reproduction (Short and Adams 1988).

Although blood plasma glucose levels have long been thought of as having direct implications on the nutritional status of beef cows, research evidence has been mixed. Selk et al. (1985) found that plasma glucose levels were correlated (r^2 =.51) with conception rates during the first year of a two year trial on PPI in first calf heifers. However, in the second year of the trial they found no correlations. Russel and Wright (1983) measured plasma glucose, 3-hydroxybutyearate and nonesterified fatty acids at various stages of the reproductive cycle of cows with different nutrient intakes. They found that glucose was not useful in evaluating energy status, 3-hydroxybutyearate was useful in pregnant cows, and nonesterified fats were useful in both pregnant and non-pregnant cows. McCaughey (1985) studied intravenous infusion of glucose in postpartum beef cows. He found glucose infusion increased levels of insulin ($P<0.05$) and decreased lipolysis in early postpartum beef cows. Yet, glucose by itself did not improve the postpartum rebreeding of cows in the trial. Garmendia et al. (1986) found that after glucose infusion, insulin increased and lipolysis decreased in response to maintain a relatively constant glucose concentration. This would imply that glucose would not be the limiting factor in determining postpartum rebreeding, suggesting that should there be a depression in blood glucose levels the opposite would occur, and we would see an increase in lipolysis. This tendency of the animal to maintain relatively constant glucose concentrations in the blood may partially explain the lack of a consistent relationship between circulating glucose concentrations and reproductive performance. Circulating glucose concentrations may regulate reproduction at a threshold level with no advantage above the threshold but severe consequences like increases in PPI and anoestrous in beef cows, should levels fall below it. More importantly than glucose - gluconeogenesis may better explain the mechanism by which nutrition alters reproductive performance in cattle (Randel 1990; Hess et al. 2005). In this context, glucose will be controlled by the sympathetic nervous system (SNS), which will be controlled by digestive absorption, gluconeogenesis, mammary gland requirements, and BC. Thus it may be the pattern of intake of specific nutrients in early lactation, and not the total energy intake, which relates most closely to the reproductive status in domestic livestock (Wade and Schneider 1992). Leers-Sucheta et al. (1994) found that high rates of glucose absorption caused greater responsiveness of LH release to infusions of GnRH in lactating beef cattle.

Although free glucose has received a lot of attention as a precursor to reproductive success, the level of BC at the time of parturition is still vitally important. First, BC is an indicator of energy reserves and recent nutritional and physiological history; it allows for flexibility in making nutritional management decisions. Secondly, and an even more important factor relates to the metabolic biology of the body. Body condition regulates glucose flux in the adipose tissue and helps to control the mixture of metabolic fuels available for the rest of the body. In this manner, BC is essential to ensure good reproductive performance.

However, the physiological and biological state of lactation does not fully explain all the differences in the ability of a cow to gain BW and BC. To clearly understand their roles we must understand how nutrients are partitioned within lactation and how the system is regulated.

1.5 Nutrient partitioning

Ruminants are important for humans because they have the ability to convert low-quality roughages into useful products, like meat and milk. Additionally they have the ability to store excess energy as fat during surplus periods, which can later be used to offset energetic shortfalls.

Regulation of nutrient partitioning involves two types of control - homeostasis and homeorhesis (Bauman and Currie 1980; Bauman et al. 1989). Homeostasis involves the operation of multiple compensatory mechanisms functioning to maintain physiological equilibrium. Homeostasis as defined by Bauman and Currie (1980) as the condition of relative uniformity which results from the adjustments of living things to changes in their environment. Thus, homeostatic controls operate on a minute-by-minute basis so that, despite acute challenges from the external environment, the internal environment remains unchanged. There are many well-established examples of homeostasis. One example for nutrient partitioning deals with the absorptive and post-absorptive periods following the consumption of a meal. In the short-term, homeostatic controls (primarily insulin and glucagon) maintain a relatively constant supply of nutrients to peripheral body tissues by promoting the storage of nutrients following a meal and the mobilization of these nutrients during the post-absorptive period.

The second type of control is called homeorhesis and was defined as the orchestrated changes for priorities of a physiological state (Bauman and Currie 1980). Homeorhetic control involves the coordination of metabolism, resulting in the directed partitioning of nutrient utilization for the processes of growth, pregnancy and lactation (Bauman and Currie 1980; Bauman et al. 1989). Thus, homeorhetic mechanisms provide chronic regulation, while homeostatic controls operate on an acute minute-by-minute basis to maintain a steady state and, in life-threatening situations, may even override the long-term regulation to preserve vital functions.

The first priority in any animal is to maintain its basal metabolism. Therefore, all energy stored or ingested will first be directed to maintaining basal metabolism. From there on energy needed for other activities is allocated according to importance. The approximate order of priority for partitioning of nutrients is as follows. 1) basal metabolism, 2) activity, 3) growth, 4) basic energy reserves, 5) pregnancy, 6) lactation, 8) reproduction 9) body fat.

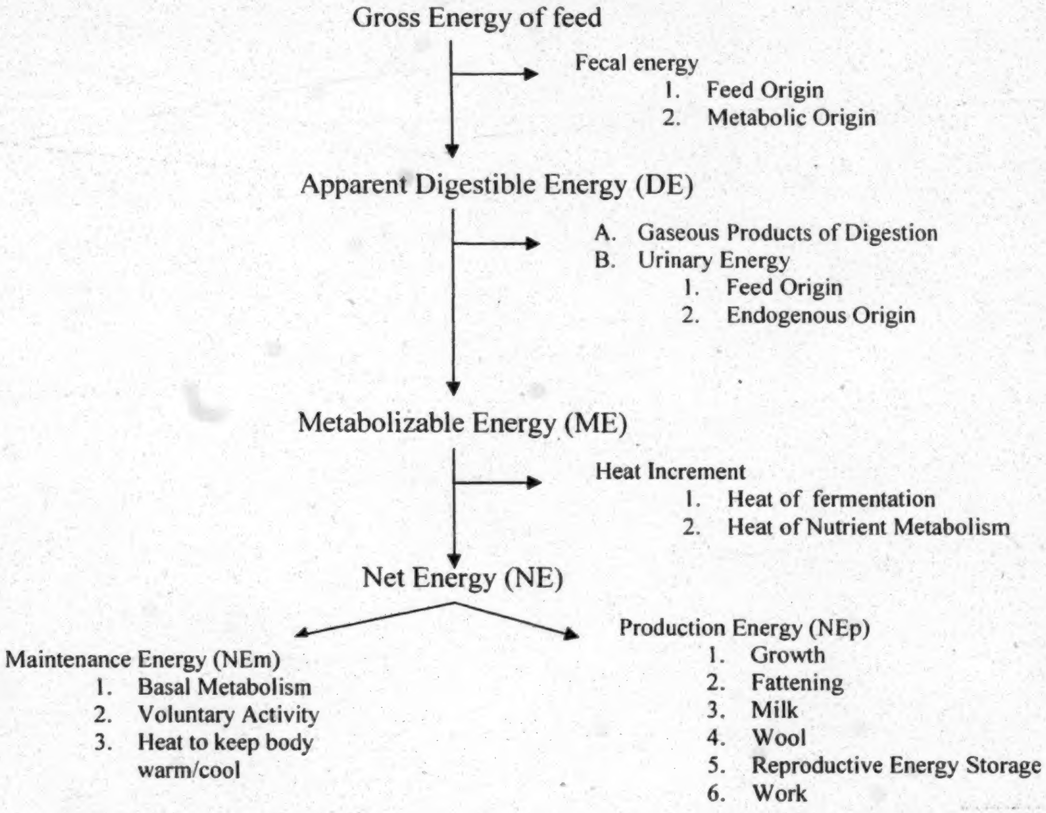
Body fat in ruminants can constitute as much as 50% of the animal's maximum possible weight (Short et al. 1990). In fact, the inadequacies of BW in describing the physiological status of beef animals is why we depend on BC scoring systems (Bellows et al. 1982). The effect of nutrition on postpartum reproduction depends somewhat on whether nutritional inadequacies exist before or after calving.

1.5.1 Nutrient partitioning - maintenance

There are many definitions of maintenance; biologically it is the process of maintaining the weight / body composition of a non-producing animal without changing its energy status (Short et al. 1990). Measuring the amount of net energy (NE) necessary for maintaining the same equilibrium in a nursing or pregnant animal is more difficult. The difficulty arises due to the many directions digestible energy has to flow to meet the ruminant's needs. Figure 1.1, demonstrates how energy is portioned in ruminants.

The main problem in determining maintenance levels in pregnant and lactating animals lies in understanding the changes in body tissue metabolism brought on by these biological states (Short et al. 1990). These biological states often increase the size and energy needs of certain organs like the liver and digestive tract. Therefore, if the biological definition of a non-pregnant/non-lactating animal is used to determine the maintenance energy needs for a pregnant/lactating animal, it would severely underestimate its energy needs.

Figure 1.1 The conventional scheme of energy utilization in ruminants (NRC, 1996)


Gross Energy of feed
Fecal energy
1. Feed Origin
2. Metabolic Origin
Apparent Digestible Energy (DE)
A. Gaseous Products of Digestion
B. Urinary Energy
1. Feed Origin
2. Endogenous Origin
Metabolizable Energy (ME)
Heat Increment
1. Heat of fermentation
2. Heat of Nutrient Metabolism
Net Energy (NE)
Maintenance Energy (NEm)
1. Basal Metabolism
2. Voluntary Activity
3. Heat to keep body warm/cool
Production Energy (NEp)
1. Growth
2. Fattening
3. Milk
4. Wool
5. Reproductive Energy Storage
6. Work

For most tissues, blood flow per unit mass parallels energy expenditure per unit of weight; in nervous tissue ratios of 5 and 6 to 1 are common (Baldwin et al. 1985). The close match between energy expenditure and blood flow reflects very precise, local regulation of blood flow according to need. This increase in blood flow may be explained by an increased need for oxygen – which indicates a higher level of energy metabolism and an increased demand for more energy metabolites (Baldwin et al. 1985). For example, energy expenditure per unit mass of the liver is 25 times greater than for muscle (Baldwin et al. 1985). This implies that there could be a relatively small change in tissue weight but greater basal energy expenditure as a ruminant moves from growth to pregnancy and then to lactation. As an example, a 50% increase in liver weight compensated by a similar weight decrease in muscle could cause a 10% increase in basal energy metabolism. In fact, some research has indicated that just the change in organ weights brought on by pregnancy alone, could cause an overall increase in the animal's energy needs by 9.5% (Table 1.1; Baldwin et al. 1985).

TABLE 1.1 Effect of lactation on organ weights and energy expenditures in lactating cows (Baldwin et al. 1985).

	Non-Lactating		Lactating	
Organ	(% BW)	(Mcal/d)	(% BW)	(Mcal/d)
Digestive Tract	3.8	1.1	4.9	1.4
Heart	0.35	1.5	0.45	1.8
Liver	1.3	3.4	1.7	4.2
Adipose	7.3	0.75	6.0	0.61
Carcass	58.0	3.9	54.0	3.6
Total	71.0	10.6	67.0	11.6

The change in organ weights may provide a partial explanation of the energy kinetics left unanswered by conventional scientific energy models (Metabolizable and California Energy Systems). As a result of weaning, improvements seen in cow BC, may simply be related to changes in organ weights, as the cow switches from lactation to non-lactation. The underlying assumption would then be that after weaning, nutrients could be redirected to lipogenesis, due to a decrease in organ nutrient demand. These assumptions are in agreement with Vandehaar (1998) who concluded that the efficiency of converting gross energy to milk is dependent on a number of variables. These variables include: body size, body tissue makeup, and diet. Efficiency of lactation will also be dependent on the production potential of the cow (Vandehaar, 1998).

Loss of body tissue during early lactation and replenishment in later lactation is an efficient process. Moe et al. (1971) calculated that the net efficiency of converting feed to body tissue and then to milk was as efficient as converting feed directly to milk. Assuming that the tissue energy in 1 unit of body condition (five-point scale, from 1 = emaciated to 5 = grossly obese) is 400 Mcal of ME and that tissue energy is converted to milk with 82% efficiency, loss of 1 body condition score during the first 60 d of lactation would provide enough energy for an additional 8 kg of milk/d (Moe et al. 1971).

If the animal prior to weaning were fed at a level that maintained its body weight and body condition, weaning would simply change the energy balance so that the animal would have a net energy surplus. Herein lies the problem of determining the maintenance expenditure of pregnant lactating animals - how is energy directed towards maintenance versus production? In fact the hormonal regulation of energy partitioning among organs may partially explain why some cows may have lower maintenance requirements and yet still support lactation without compromising body condition (Baldwin et al. 1985).

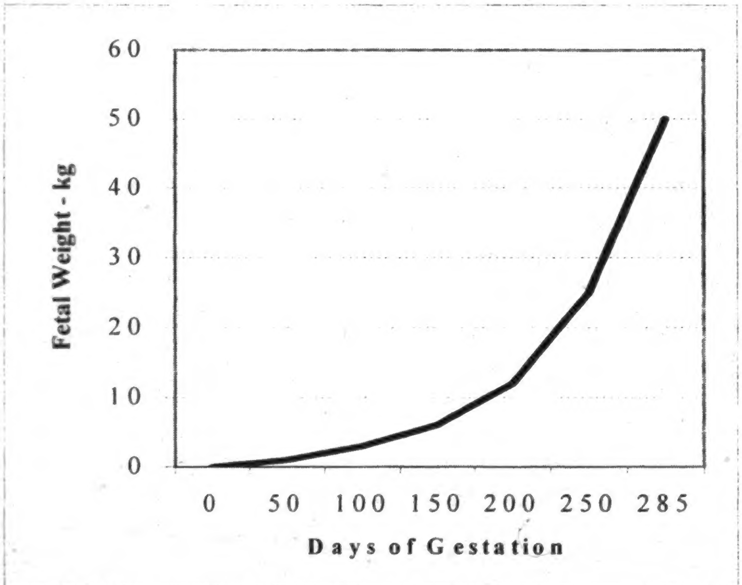
Similarly, as metabolizable energy availability increases, more energy can be diverted to lipogenesis. The uncertainty regarding the distribution of energy between milk and body tissue is referred to as the "Partitioning Problem" (Moe and Tyrrell 1975). The extent of body fattening is a function of both the genetic potential of the animal and the total energy within the diet. In addition the nature of the diet and/or the type of diet can strongly influence the energy partition between milk production and body fat accretion (Moe and Tyrrell 1975). As diets decrease in their metabolizable energy content, the ability of animals to produce fat becomes compromised, and may in fact, call for a mobilization of fat reserves to sustain milk production (Randel 1990). This is often seen as is the case in the Canadian and Western United States cow/calf production systems, where there is a rapid decrease in forage quality during the later stages of the growing season while the cow is still trying to lactate (Weder et al.1999).

1.5.2 Nutrient partitioning - pregnancy

Pregnancy imposes a great nutritional strain on an animal and in some cases can be as much as 75% greater than non-pregnant animals of the same weight (Bauman and Currie 1980). Thus, in keeping with the concept of partitioning, a great deal of homeorhesis must occur in order to direct the nutrients needed to sustain pregnancy. This is more clearly demonstrated by looking at the growth curve of the bovine fetus during pregnancy.

Figure 1.2 shows that the fetus achieved only 30% of its birth weight during the first 7 months of gestation. The bulk of the weight gain occurs during the last two months and clearly shows the need for substantial energy partitioning in order to maintain a healthy pregnancy. The nutrients required to do this is equivalent to about 4.5-kg milk/day (Bauman and Currie 1980).

Figure 1.2 Growth profile of bovine fetus during pregnancy (Bauman and Currie 1980).



Not shown in Figure 1.2 is the growth of the mammary and placental tissue. The bulk of mammary tissue development also happens to coincide at precisely the same time as maximal fetal growth. This development only adds more to the metabolic burden of pregnancy.

One thing that differentiates the bovine fetus from those of many other species is that it cannot merely be classified as a "passenger" (Bauman and Currie 1980). The ruminant fetus is more vulnerable than that of many species to swings in maternal nutrition, and severe retardation can result from chronic malnutrition (Bauman and Currie 1980). Thus, nutrient partitioning during the later stages of gestation by homeorhetic signals is of vital importance. Typically, 50-70% of the glucose required for bovine fetal growth is supplied by oxidative metabolism, however within two days that level can be cut in half should there be maternal starvation.

1.5.3. Nutrient partitioning - lactation

Following parturition, the partitioning of nutrients during lactation becomes much more complicated. There are many systems involved in the initiation, regulation and maintenance of this biological function, however understanding the regulatory mechanisms is important to understanding how they affect body condition and subsequent reproductive performance.

1.5.4 Somatotropin

One of the most important hormones that alters nutrient partitioning during lactation is somatotropin. Somatotropin (ST) is a hormone that applies a homeorhetic control by shifting the partitioning of nutrients in an animal so that lactation and milk synthesis can be sustained. Lactation involves the metabolic coordination of various body organs and tissues and includes the metabolism of all nutrient classes - carbohydrates, lipids, proteins and minerals (Monsanto 1995). The adaptations of ST can be broadly divided into two segments – first, the direct effects on the mammary tissues and secondly, the indirect effects on the system mediated by insulin-like growth factor (IGF-1).

Directing nutritional inputs toward anabolic processes has tremendous connotations with regard to reproduction. The somatotropic axis has been implicated in mediating metabolic status centrally (Hess et al. 2005). However, a central role for GH on the reproductive axis is difficult to reconcile because GH secretion is downstream from the hypothalamus and is controlled by hypothalamic secretions (Hess et al. 2005). Likewise, bovine ovarian follicles are nearly devoid of GH receptors although GH may exert direct actions on luteal cells (Hess et al. 2005). Growth hormone regulates expression of the IGF-I gene in extrahepatic tissues (Hess et al. 2005) in addition to its classical role in stimulating hepatic expression and secretion of IGF-I in nutritional modulation along the hypothalamo-hypophyseal-ovarian axis (Armstrong and Benoit 1996; Wettemann and Bossis 2000; Wettemann et al. 2003). Interestingly, insulin interacts with GH to control hepatic IGF-I production (Hess et al. 2005). Serum concentrations of IGF-I increased from wk 2 to 10 in beef cows that resumed estrus early postpartum but not in cows that remained anestrous (Hess et al. 2005). Armstrong and Benoit (1996) suggested that IGF-I may act via autocrine, paracrine, and endocrine mechanisms because, in addition to the presence of IGF-I receptors, mRNA for IGF-I has been detected in the ovary and median eminence. Regardless of the hormone's origin, IGF-I is a positive signal to the hypothalamo-hypophyseal-ovarian axis.

The direct actions of ST appear to be primarily concerned with the coordination of metabolic processes primarily within the adipose tissue. Adipose tissue has two main functions, lipogenesis and lipolysis. Specifically ST alters adipose tissue response to homeostatic signals affecting lipid synthesis and lipid mobilization. Somatotropin reduces the ability of insulin to stimulate lipogenesis and enhances the ability to stimulate lipolysis. Somatotropin does not alter the attachment of insulin to its binding site but rather inhibits or prohibits its synthesis. The inhibitory effect of ST on lipogenesis works by blocking protein synthesis within the adipose tissue. The mechanism is in fact consistent with the existence of second messengers, which arise from the somatotropin receptor binding sites, which biologically inhibit the response to insulin. The second messenger will then enter the adipocyte and inhibit the insulin protease necessary for the normal action of insulin (McNamara 1995). This theory has been tested and it was found that the adipose tissue from pregnant and lactating cows possesses a specific insulin protease that shares the same characteristics as insulin protease from other sources (Marinchenko et al. 1992). Blocking the release of prolactin during early lactation not only stopped the synthesis of milk in dairy cattle but also resulted in an increase in lipogenesis and decreased rates of lipolysis (Bauman and Currie 1980). If a cow is in a positive energy balance in terms of energy intake when ST is initiated, then the body will not necessarily have to redirect fat stores in order to support the energy needs of milk synthesis. However, if the cow is near zero or in negative energy balance, ST will force the animal to rely on body fat reserves that are mobilized to support the nutrient needs for milk synthesis. In this case the animal will have three options; increase its voluntary feed intake, increase feed quality or reduce lactation in order to return to a positive nutrient balance (Monsanto 1995). Differences in the quality and quantity of pasture may explain why many beef cows can gain BW during peak lactation and yet lose BW in the fall even though cows are on the downward curve of milk production.

1.5.5 Insulin like Growth Factor-1

Somatotropin also indirectly affects the mammary gland via the actions of insulin like growth factor-1 and together they play vital roles in the regulation of lipogenesis (Jolly et al. 1993). In late pregnancy and early lactation, adipose tissue becomes resistant to the normal actions of insulin and in fact there is a reduction in lipogenesis (McNamara 1995). The enzyme that is primarily responsible for the action of insulin and somatotropin is acetyl-CoA carboxylase, which is the primary rate-limiting enzyme in fatty acid synthesis from glucose or acetate. Thus, the theory that weaning simply diverts energy from milk production to fat production is too basic. Lipogenesis is regulated hormonally and ST and IGF-1 play a vital role in its regulation. Insulin-like growth factor binding protein-2, -3, and -5 have been detected and are produced (Roberts et al. 2001) in the anterior pituitary gland of cycling beef cows.

The anabolic effects of systemic IGF-I are related to relative abundance of IGFBP-3 (Armstrong and Benoit 1996; Boisclair et al. 2001) whereas IGFBP-2 is associated with poor nutritional status (Armstrong and Benoit 1996). Concentrations of IGFBP-2 in serum of beef cows at 2 wk postpartum diminished, and concentrations of IGFBP-3 increased in cows that resumed estrus by 20 wk postpartum compared with anestrous cows (Hess et al. 2005).

Expression of mRNA for IGFBP also occurs in the ovary (Hess et al. 2005), and IGFBP-2, -3, -4, and -5 have been detected in the ovarian follicular fluid of beef cows (Funston et al. 1996). Follicular fluid concentrations of IGFBP-2, -4, and -5 are high in small- to medium-sized and larger atretic follicles, but decrease in the dominant follicle (Armstrong and Benoit 1996; Wettemann et al. 2003). Insulin-like growth factor binding protein-3 was the only IGFBP detected in fluid from the preovulatory follicle (Funston et al. 1996). Heifers consuming increased dietary energy had reduced concentrations of mRNA for IGFBP-2 and IGFBP-4 in small follicles (Armstrong et al. 2001). Based on these observations, IGFBP must be considered potential mediators of nutritional inputs into the reproductive axis.

Besides the immediate hormonal influence of ST and IGF-1, lactation will also be affected by several other factors, which also have a profound effect on the nutrient partitioning within the animal.

These factors will include:

- *Genetic potential for milk production*
- *Nutritional history of the animal*
- *Stage of lactation*
- *Level of nutrition*
- *Type of diet*

The influence and impact of these factors will vary. However, at this time little research has been done as to the direct impacts of these factors within the partitioning process of beef cattle. In fact, total milk production for beef cattle has typically been calculated without isolating these factors and so it is difficult to establish their cumulative effect. However it is well known by nutritionists that manipulation of the last two factors through ration and feed changes can have profound effects on total milk yield (Moe and Tyrrell 1975).

1.6 Lipogenesis

Lipogenesis is the process of conversion of glucose and its intermediates like pyruvate, lactate and acetyl CoA to fat. The main factors controlling the rate of lipogenesis are related to the nutritional status of the animal. Rates of lipogenesis are greater in well-fed animals, versus a calorie deficient or insulin deficient animal (i.e. Diabetes) (McNamara 1995). For lipogenesis to occur there must be a high concentration of serum free fatty acids (McNamara 1995). The source of the long chain fatty acid can either be a dietary lipid or synthesized from Acetyl-CoA, which would be derived from a carbohydrate. In the adipose tissue, fatty acids may be oxidized to acetyl-CoA (beta-oxidation) or esterified to acetylglycerols.

Typically, fats are stored as a triacylglycerol (Chapman, 1996).The triacylglycerol stores in adipose tissue are continually undergoing lipolysis (hydrolysis) and re-esterification. Both of these pathways involve different reactants and enzymes. This allows many of the nutritional, metabolic, and hormone factors that regulate the metabolism of adipose tissue to work on the process of lipogenesis or on lipolysis. The end product of these two processes determines the amount of free fatty acids in adipose tissue and the level of free fatty acids circulating in plasma (Chapman 1996).

1.7 Lipolysis

Lipolysis, which is the release of lipid from adipose tissue, is no less complicated than lipogenesis and in fact involves many of the same factors as lipogenesis. In high producing dairy cattle, where lactation peaks at three to four weeks post-partum lipolysis is often the sole source of energy that can sustain such high peaks in lactation beyond the caloric content of the ration being fed (Bauman and Currie 1980). In many instances, a zero energy balance is not achieved until milk production returns to 80% of peak production. During the first 10 weeks of lactation the NE deficiency can be the energy equivalent of 50 kg of pure lipid (Bauman and Currie 1980). Bauman and Currie (1980) proposed that up to an 80% glucose turnover is required during maximum mammary secretions. Under normal management conditions the cow will have to make up for this BW and BC loss over the last third of her lactation in order to replenish her body reserves in preparation for her next lactation. But what governs and controls lipolysis?

Lipolysis may be partially regulated by the insulin resistance of adipose tissue during early lactation (Bauman and Vernon et al. 1993). However, insulin concentration or binding alone can not account for the wide variation in rates of lipolysis throughout lactation. As in lipogenesis, somatotropin plays a vital role in lipolysis. Somatotropin increases the responsiveness of adipose tissue to beta-adrenergic agents by increasing the number of beta-receptors. This makes the adipose tissue more responsive to adenosine. Although adenosine limits lipolysis, the somatotropin may be acting to partially remove this limitation and thus, increase lipolysis during early lactation (McNamara 1995). Simply put if lipogenesis is inhibited, lipolysis is accelerated.

However, the biochemical reaction of somatotropin is not the only regulatory system governing lipolysis. The function and influence of the thyroid system is also important. The thyroid system plays an integral part in regulating the amount of cyclic adenosine monophosphate - cAMP. Cyclic AMP levels were three times greater per gram of adipose tissue and five times greater per mg of cellular protein in dairy cattle in the first two months postpartum of lactation compared to the last month prepartum (McNamara et al. 1992). Thus, one of the mechanisms by which adipocytes increase their sensitivity to lipolytic stimulation during lactation may be a tighter molecular connection between cAMP, protein phosphorylation, and hormone–sensitive lipase activity.

1.8 Gluconeogenesis

Ruminants only absorb limited quantities of glucose from the gastrointestinal tract – the majority of metabolites are absorbed as volatile fatty acids (VFAs). Of all the VFAs - propionate is the primary gluconeogenic VFA absorbed (Bergmann 1973). Abomasal infusion of propionate has been shown to enhance blood glucose concentrations and release LH following a GnRH challenge in prepuberal heifers (Rutter et al. 1983).

One of the ways to shift VFA production ratios is through the feeding of ionophores, such as lasalocid and monensin. Feeding ionophores will shift the VFA proportion to greater levels of propionate (Moseley et al. 1977; Short and Adams 1988). Results of feeding ionophores to replacement heifers and growing bulls have demonstrated a reduction in the age and weight at puberty (Moseley et al. 1977; McCartor et al. 1979). Similarly changing a ration from a high roughage component to greater amounts of concentrates will also result in a shift of VFA production to greater amounts of propionate (McCartor et al. 1979).

Propionate increases the ovarian response to endogenous and exogenous gonadotropins and enhances the release of LH following a challenge with either GnRH or estrogen (Randel 1990). Randel (1990) demonstrated this hypothesis in a trial where monensin was fed to lactating postpartum beef cows. He found that the ionophore increased the release of LH following GnRH challenge and enhanced release of LH following an estradiol challenge and that the cows returned to estrus sooner (Randel 1990).

It is postulated that an increase in gluconeogenesis occurs when there are elevated levels of propionate (Randel 1990). With an increased level of propionate, dependency upon amino acids for gluconeogenesis would be decreased. Freeing up more amino acids would have a direct effect at the hypothalamic-pituitary-ovarian axis, which would result in an increase in the secretion of GnRH from the hypothalamus and an increase in the pulsatile secretion of LH from the pituitary. It is probable that increased supplies of metabolizable amino acids or perhaps specific amino acid imbalances, are detected by the regions of the brain responsible for LH release (Hess et al. 2005). It is possible that blood-borne metabolites exert their effects indirectly by influencing hormones purported to be involved in modulating the hypothalamo-hypophyseal-ovarian axis (Hess et al. 2005).

1.9 Nutrition and pituitary function

Mean serum concentrations of LH are lower in postpartum cows losing BC rather than those maintaining BC (Randel 1990). Diets that are either low in energy or protein, lead to lower pulsatile releases of LH, indicating that an increased concentration of gonadotropin is stored in the pituitary gland and cannot be released following a GnRH challenge. Data indicates that hypothalamic release of GnRH is being suppressed, which proves that the nutritional status of the postpartum cow alters pituitary release of LH following a GnRH challenge (Randel 1990).

Increased pulsatile secretion of LH from the pituitary stimulates ovarian function and results in the return to estrus with ovulation and subsequent development of a functional corpus luteum. The compound or compounds that are detected by the hypothalamic-pituitary-ovarian axis may be energy-related compounds, amino acids or catabolites (Randel 1990).

Other evidence indicating that nutrition affects the hypothalamic release of GnRH has been obtained by the use of estrogens to stimulate the release of LH (Randel 1990). In early postpartum stages and with severely restricted diets, cattle have had complete failure responding to a challenge of estradiol-17B. The reduced ability of cows receiving diets with lower energy levels to respond to estradiol suggests that the hypothalamic responsiveness is due to a decrease in estradiol receptors as well as faulty synthesis, storage and secretion of hypothalamic GnRH. This suggests that the nutritional control over postpartum rebreeding in cattle is controlled by the hypothalamus (Randel 1990).

1.10 Sympathetic nervous system

Another regulator of glucose and fatty acid metabolism in the adipose tissue is the sympathetic nervous system (SNS) (Landsberg 1990). When the intake of energy is decreased, the release of norepinephrine (NE) from the SNS to brown and white adipose tissue is altered, theoretically to conserve energy. In rats, where the NE was artificially decreased by injection of alpha-methylparatyearosine (AMPT), which blocks the synthesis of NE, there was an increase in lipogenesis. In obese rats, the accumulation of fat has been linked to lower levels of NE (Knehans and Romsos 1983). This further suggests that the SNS plays a vital role in the regulation of lipolysis during lactation. Whether this adaptation plays an important role in early lactation remains unclear; however, the rise in SNS release of NE later in lactation is consistent with the elevated rates of lipolysis found in rats and cows.

Table 1.2 shows the results of a study in which the activity of the SNS was estimated by measuring the turnover of NE, using AMPT, a blocker of NE synthesis. In that experiment it was clearly shown that the SNS had a strong influence in controlling NE synthesis (McElroy et al. 1986).

Table 1.2 Norepinephrine content and turnover in adipose tissue of virgin, pregnant, or lactating rats (McElroy et al. 1986).

	Day 18 Pregnancy		Day 21 Lactation	
Adipose Tissue	Basal	3 hours after AMPT	Basal	3 hours after AMPT
Perimetrial				
Virgin	31.8	13.8	19.6	12.9
Bred	16.2*	11.1**	38.5*	24.6**
Retroperitoneal				
Virgin	22.2	12.7	12.6	15.3
Bred	15.4*	7.7**	32.2*	23.2**

*Bred vs. virgin and pregnant vs. lactating, ($P<0.05$).
**Rate of turnover due to injection of AMPT different between bred and virgin, ($P<0.05$).
Number of animals was 5 to 7 for each group.

In dairy cattle, rates of lipolysis remain deviated after peak lactation, even though feed intake has increased, somatotropin has decreased, energy balance is positive, and rates of lipogenesis have markedly increased (McNamara 1994). This apparent uncoupling of regulation leads to the belief that the SNS plays a vital role in fine tuning the regulation of lipolysis and lipogenesis to meet both the needs of the lactating animal and the need to increase adipose reserves after peak lactation. The adaptation of the SNS seems to be a secondary adaptation to extending lactation, and is probably acting in addition to regulation by insulin and somatotropin.

1.11 The influence of suckling

Biologically, suckling has a wide effect on estrus in domestically farmed species. The effects range from complete anestrous in pigs, to no effect on ewes, to an intermediate effect in cattle (Williams 1990). Suckling is still however a very important factor determining PPI and BC in cows (Short et al. 1990). Suckling has been shown to prolong the postpartum anestrous period in beef and dairy cattle (Wetteman et al. 1978; Zalesky et al. 1984). In some instances, research has shown that PPI is even proportional to sucking frequency (Zalesky et al. 1984; Jaeger et al. 1987). The exact mechanism by which suckling extends the postpartum anestrous period remains unclear. The possible relationship of nutritional intake and lactation stress coupled with the need for continued body growth and hormonal signals spurred on by suckling may all be factors. However to fully understand the implications of suckling, a differentiation needs to be made between lactational stress and the physical aspect of suckling.

A well-known study by Short et al. (1972) compared postpartum intervals of suckled, non-suckled and mastectomized cows. The PPI in the experiment was 65 d, 25 d and 12 d respectively. By adjusting nutrient intake to maintain constant BW among groups, these authors concluded that both suckling and the growth within mammary glands could delay postpartum estrus independent of lactational energy demands.

Although most research dealing with the impact of suckling frequency has focused on PPI, little research has focused on suckling and its implications on hormonal changes that affect the nutritional status of the dam. Hormonal studies that have been done have mostly focused on suckling and the implications on the reproductive hormones, specifically LH and GnRH. Work done on these hormones has conclusively established that suckling suppresses the release of LH from the anterior pituitary gland during the early postpartum period (Carruthers and Hafs 1980; Carruthers et al. 1980).

The fluctuations in the release of LH during the postpartum period are thought to be a direct reflection of the release of GnRH from the hypothalamus (Carruthers et al. 1980).

Jaeger et al. (1987) found that the response of the bovine pituitary to GnRH during the post-partum period was not influenced by the act of suckling but was rather affected by the post-parturition time. On the other hand, Wetteman et al. (1978) and Randel (1981) demonstrated that suckling intensity was a major contributing factor to the length of the PPI. More than likely though it would seem that some form of nutrient partitioning would explain the differences in these trials. Particularly since the majority of experiments that have shown positive results have involved primiparous beef heifers (Bellows et al. 1974). These experiments have also shown that the greatest benefits of early weaning have been with poorer conditioned first and second calvers, by reducing the lactation stress and thereby improving their overall conception rates (Laster et al. 1973; Randel 1981).

1.12 Conclusion and review

The purpose of this Chapter was to briefly review the mechanisms and show how the demands of lactation and pregnancy affect the metabolism of energy-yielding compounds in adipose tissue. Although many of the references presented in this chapter have been from dairy cattle research, their principals still hold true for beef cattle, because the mechanisms that control lipolysis and lipogenesis are identical. In identifying the physiological differences between lactating and non-lactating pregnant animals it is important to understand how lipogenesis and lipolysis is regulated.

Even though many differences in BW and BCS between lactating and non-lactating pregnant cows can be explained by these hormonal reactions, there are still many other factors that have an important influence. In fact, a good proportion of the metabolic difference may lie in diet quality and type, as well as phenotypical differences between different animals. It may partly be related to genetic differences in how nutrients are portioned to different organs and the relationship of nutrient utilization.

Regulation of nutrient partitioning to support fetal development and milk synthesis is complex. There has been much research focused on PPI up until the point of conception but little concerning post-conception metabolic control parameters. Herein lays the key to understanding how suckling affects the whole system of lipolysis/lipogenesis. Improvement in this area will require more research to understand the physiological controls of lipogenesis and lipolysis. There needs to be a better understanding of the regulatory mechanisms, to better plan preventive methods of managing cow BW and BC.

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CHAPTER 2

A REVIEW OF THE EFFECTS OF WEANING ON CALF PERFORMANCE, DIGESTIVE SYSTEM DEVELOPMENT, SEXUAL DEVELOPMENT, ANIMAL BEHAVIOUR AND CARCASS QUALITY.

2.1 Introduction

In Alberta the average starting date for the calving season is March 1st and on average weaning occurs around the 28th of October AAFRD (1999); this makes the average age of calves at weaning around 210 days or seven months. Thus the majority of the cow/calf production systems in western Canada are based on late winter to spring calving, nursing the calf on the cow for the summer and then weaning the calf in late October to early November.

If forage resources and quality are adequate, weaning in late October can provide adequate calf gains and leave the dam with sufficient body condition so that minimal supplementation is required prior to next year's calving and breeding season. However, if pasture growth is reduced due to drought or if pasture resources run out, the producer will either have to feed hay or grain in order to maintain cow body condition and desired calf weight gain. The costs associated with extra supplementation or longer days of winter feeding can make the difference of whether or not the cow/calf operation is profitable for that year (Myers et al. 1999b).

Drought may not be the only circumstance where early-weaning of calves is warranted. Many cow/calf operations rely on crop residues after grain harvesting as a resource for extending the grazing season. This integrated approach of coupling crop production with a cow /calf operation offers tremendous opportunity for reducing costs of production. However the downfall with utilizing crop residues as a low cost feed alternative is that they are insufficient in meeting the high nutritional requirements of a growing calf and lactating beef cow. To utilize crop residues the calf needs to be weaned so that the cows nutritional requirements better match the forage resource.

Weaning calves earlier (90-180 days) rather than weaning at the traditional 205 days has been shown as a solution for dealing with variations in forage quantity and quality (Lusby et al. 1981; Peterson et al. 1987; Myers et al. 1999). To increase the profitability of the cow/calf sector, management practices that reduce the nutrient requirements in both digestible energy and protein need to be adopted; changing the age at weaning is one of those management practices (Pratt, 2004).

2.2 Early-weaning and calf performance

Feed costs account for 54 to 75% of the annual cost of keeping a cow (Taylor 1984). Energy is the nutrient required in the greatest quantity by beef cattle, with about 70% of the energy consumed by a cow going to maintenance (Ferrell and Jenkins 1984). Peterson et al. (1987) reported that early-weaned cow/calf pairs (110 days) were 43% more efficient in converting total digestible nutrients into calf gain than were normal weaned cow/calf pairs (210 days). In this same study, Peterson et al. (1987) found that early-weaned cows consumed 20% less total digestible nutrients than non-weaned pairs after weaning.

Although the benefits of early-weaning on improving reproduction and reducing feed inputs to the cow have been recognized for many years, the factors limiting practical application of early-weaning, has been the management of the early-weaned calf itself (Lusby et al. 1981; Fluharty et al. 1996). It is important to review some of the previous findings on weaning management to identify the gaps in the research that were inconclusive or remained unanswered.

Most of the research on the weaning of spring born calves has looked at management programs focused on feedlot feeding programs (Lusby et al. 1981; Fluharty et al. 1996; Myers et al. 1999). Myers et al. (1999) examined three weaning scenarios in spring born beef calves. The steer calves were 1) early-weaned (170 d) and placed on a finishing diet (EW), 2) normal weaned (225 d)and creep fed with grain for the last 55 d prior to weaning and then placed on a finishing diet (NWC), or 3) normal weaned (225 d) without creep feed and then placed on a finishing diet (NW). The results showed that in the first 55 d (d 170-225) EW steers gained 100% faster (P=0.0001) than the average of NWC and NW steers. When NWC and NW steers were compared, NWC steers had a 32% faster (P=0.02) rate of gain. Once the calves were placed on feed, EW steers had lower intakes (7.70 vs. 8.16 kg/d, P=0.008) and better gain:feed conversions (0.170 vs 0.153, P=0.002) than the average of NWC and NW steers. At the time of normal weaning, cows with EW calves were 40 kg heavier than NWC and NW (P=0.0001) and EW cows had 0.23 units higher BCS (scale 1-9, P=0.04) than NWC and NW.

In another study Fluharty et al. (1996) looked at 1) the effects of time of weaning (100 vs 205 d), 2) nutritional regimen, and 3) the diet prior to 205 days on steer performance and carcass characteristics. Steers were allotted to one of two treatments early-weaned (100 d) or normal-weaned (205 d). The early weaned steers were then split into one of four nutritional regimens 1) 100% concentrate @ 12% CP, 2) 100% concentrate @ 16% CP, 3) 90% concentrate @ 16% CP and 4) 60% concentrate @ 16% CP. Normal-weaned calves remained with their dams throughout the summer and at 60 d prior to weaning, the pairs were split into two treatments 1) creep (60% concentrate pellet @ 16% CP) and 2) non-creep fed control. At 205 days the normal-weaned steers were weaned and all calves were placed on a 90% concentrate ration @ 14% CP until they reached 900 lbs, the ration was then adjusted to a 90% concentrate @ 12.5% CP until the steers reached the target market weight of 534 kgs.

The effects of diet and creep feed status on weight and ADG of calves from 100 to 205 days of age are shown on Table 2.1. Early weaned calves that were fed either 100% or 90% concentrate diets had heavier (P<0.01) weights at 205 days of age and had greater (P<0.001) ADG from 100 to 205 days of age compared with normal-weaned calves. Early-weaned calves fed a 60% concentrate diet were intermediate in 205-d weight and ADG.

Further evaluation of the weaning treatments found that early-weaned calves fed either 100% or 90% concentrate diets had greater overall ADG (P<0.01) and feed efficiency (P<0.001) compared with calves fed 60% concentrate diets. There were no differences (P>0.10) in dry matter intake (DMI).

Table 2.1 Effects of diet and creep status on weight and ADG of calves from 100 to 205 days of age (Fluharty et al. 1996).

	Early-weaned				Normal-weaned	
Item	100 % Conc. 12%CP	100% Conc. 16% CP	90 % Conc. 16% CP	60 % Conc. 16% CP	Non - creep	Creep-fed
Initial wt kg.	149.1	144.1	142.7	144.5	154.5	152.3
Final wt kg.	277.3^{a}	275.0^{a}	277.7^{a}	258.6^{ab}	253.6^{b}	253.6^{b}
ADG – kg /day	1.25^{a}	1.28^{a}	1.32^{a}	1.12^{b}	0.99^{c}	0.99^{c}

^{abc} Means within a row with different superscripts differ ($P<0.01$)

There were also no differences ($P >0.10$) in finishing period performance due to diet prior to 205 days of age. Twenty percent of the steers fed the 100% concentrate diet @ 12% CP failed to reach the 534 kg live slaughter weight compared with no steers fed the 60% concentrate diet or weaned at 205 days of age that failed to reach the same weight.

Fluharty et al. (1996) concluded that early-weaning of calves onto a 100% concentrate diet might cause problems late in the feeding period. Carcass characteristics were also studied, steers fed the 90% concentrate @ 16% CP had a greater ($P<0.05$) marbling score compared with calves weaned at 205 days of age. Steers that were fed a 100% concentrate at either 12% or 16% CP had back fat measurements of 17 mm and 16.5 mm, respectively. The authors concluded these back fat and yield grade values may be unacceptable to the beef industry compared with the 60% concentrate and calves weaned at 205 days of age. The author also concluded that evaluating the calves for breed type, frame score and perhaps using a more aggressive implant program may be warranted with early-weaned calves fed high-concentrate diets.

Lusby et al. (1981) studied the effects of very-early-weaning (<90 days) and back-grounding using 63 first calf Angus x Hereford crossbred pairs. The pairs were assigned to one of three treatments; 1) normal-wean (NW - 205 d), 2) early-wean feedlot (EWD -56 days) and 3) early-wean feedlot-pasture (EWDP – 56 days). The calves that were early-weaned were split at 135 days; one group remained in the feedlot while the others were placed on native pasture with access to a 70% concentrate-creep.

Table 2.2 Weight gains, weaning weights, and feed efficiencies of suckled and early-weaned calves (Lusby et al. 1981).

		Treatments	
Item	**Suckled**	**Feedlot**	**Feedlot-Pasture**
Number of calves	30	16	13
Conception rate of dam	59%	97%	97%
Weight at early weaning - kg		56.3	57.2
Gain d 56 – 135	57.6	48.1	28.1
Weight at normal weaning - kg	169.3	169.8	149.8
Feed : Gain ratio		4.2	4.3
Feed costs/calf		$82.19	$64.49
Pasture charge			$10.00
Total costs		$82.19	$74.49

Weaning weights (Table 2.2) were similar for NW and EWD calves. Early-weaned feedlot-pasture calves were 20 kg lighter at the time of normal-weaning than NW and EWD calves, suggesting that calves of this age must have either a complete mixed diet or a better quality forage than that used in this study to make adequate gains without milk. The authors also concluded that the poor performance of the feedlot-pasture calves was probably also related to a digestive system that was not completely developed in the early stages immediately post weaning; thereby limiting the growth rates of those calves.

Feed costs (Table 2.2) were $82.19 for EWD calves and $64.49 for EWDP. The authors concluded that the economic feasibility of early-weaning would be dependent upon the expected rebreeding potential and the amount of feed that would be needed to carry the cow herd as in the case of drought. Any economic comparison would also have to consider the expected calf crop for the succeeding year after early-weaning. In the case of this study, the difference in conception rates between normal-weaned and early-weaned first calf heifers was 59.4% versus 96.8%.

In general most literature (Wyatt et al. 1976; Lusby et al. 1981; Lusby and Wettemann 1986; Lusby et al. 1990) agrees that feeding programs for young (2-5 month old) calves need to be "growing programs" that hold ADG levels similar to those achieved on the cow. These rates of gain will generally range from 0.9 to 1.1 kg/day depending on frame size and growth potential of the calves. Otherwise, full-fed early-weaned calves would not finish at acceptable slaughter weights.

2.3 Early-weaning and rumen development:

To understand the variation in performance of early-weaned calves a clear understanding of the changes and development in the postnatal rumen is needed. What makes the ruminant animal distinctive is the four separate stomach compartments in the digestive system; the rumen, reticulum, omasum and abomasum. This four-stomach system coupled with microbes that have the ability to digest high quantities of roughage that are high in lignified material and hemi-cellulose is what makes ruminants unique.

Data cited by Warner and Flatt (1965) indicated that the stomach composition in adult cattle is distributed 81-87% in the reticulo-rumen, 10-14% in the omasum, and 3-

5% in the abomasum. Chandler et al. (1964) found the stomach contents of 15 wk-old weaned calves were distributed 86, 7 and 7% respectively, figures that agree well with those of adults. Hodgson (1973) studied the stomach contents of 10-13-week-old calves weaned on various types of roughage diets. He found that 79-92% of the wet digesta was recovered from the reticulo-rumen, 3.4-11.3% from the omasum, and 1.9-10.6% was from the abomasum.

To better understand the importance of the changes that occur within the ruminant digestive system a brief review of the primary functions is needed.

2.3.1 Rumen

In a newborn calf, the rumen is very small and the calf is functionally a monogastric. The greatest developmental growth in the rumen is from two to three weeks of age until six months of age; thereafter, any subsequent growth will be proportional to the total growth of the animal (Church 1975). This early period of growth is where the specialized function of the rumen is first established. The primary function of the rumen is to serve as a fermentation vat where microorganisms including bacteria, protozoa and fungi break down the feed. Eventually the rumen in a mature cow becomes very large and in many cases is capable of holding 160-200 litres of material.

2.3.2 Reticulum

The reticulum is an extension of the rumen. The reticulum, by means of regular contractions, aids in keeping the feed in the rumen mixed with water and saliva until it has a consistency that can pass into the lower digestive tract.

2.3.3 Omasum

The omasum serves mainly as a dehydration area. As the feed passes through the omasum it is squeezed and compressed by the contractions of the omasum. This removes 60 to 70 percent of the water from the partially digested feed (ingesta). The omasum also serves for absorbing an estimated 40-69% of all volatile fatty acids (Lane et al. 2000). Once water and the volatile fatty acids are absorbed into the lining of the omasum they are then shuttled into the blood stream and circulated throughout the body.

2.3.4 Abomasum

The abomasum is referred to as the "true stomach" it is the stomach that most closely represents the stomach in monogastrics. As the feed passes into the abomasum, gastric juices secreted by the abomasum are mixed with the ingesta, producing a material about the same consistency of that in the rumen. The high acid content of the gastric juices lowers the pH rapidly and kills the protozoa and many of the bacteria. The ingesta passes rapidly through the abomasum into the lower tract, where absorption is completed in a similar manner to monogastrics.

During the early period of postnatal growth, the specialized function of the rumen is established. Tamate et al. (1962) were one of the first groups of researchers to study the stomach development of early-weaned calves. Their work was based on dairy calves, which under normal management practices are weaned off milk at 8 weeks or less. Observations indicated that a rapid development occurred in the reticulo-rumen as early as four weeks of age. At eight weeks it occupied the entire left half of the abdominal cavity, except for a small space filled by the anterior part of the body of the abomasum, and extended considerably into the right half. The differential development of the compartments of the stomach in bovines has also been intensively investigated by Church (1975). Data from several of those experiments has been complied in Table 2.3.

Table 2.3 Digestive system composition in dairy calves from birth to 38 weeks of age (Church, 1975).

	Age in weeks						
	0	4	8	12	16	20-26	34-38
Reticulo-rumen	38	52	60	64	67	64	64
Omasum	13	12	13	14	18	22	25
Abomasum	49	36	27	22	15	14	11

The information compiled in Table 2.3 indicates a rapid increase in the size of the reticulo-rumen as soon as the animal starts to ingest dry feed. The abomasum regresses in relative size, although not in absolute size and the omasum develops slowly, taking longer to reach mature size than the reticulum or rumen. The reticulo-rumen of dairy calves makes its most rapid relative growth prior to eight weeks of age, and the full relative size is attained by 12 weeks. Variances in the size of the reticulum and rumen will also depend upon the nutritional composition of the calf's diet (milk vs. dry feed) (Church 1975). The higher the energy and protein density of the feed the less will need to be consumed to meet the nutritional requirements of the calf.

At week 34-38 the omasum is still increasing in relative size while the abomasum is still regressing. For comparison the growth and size of the stomach in other ruminants can be quite different. In lambs the reticulum can reach its relative mature size by 30 days. Rumen growth is more marked and it is of mature relative size by eight weeks of age. As for the omasum it is still undersized at eight or nine week, although the abomasum is of relatively mature size (Church 1975).

Much work on stomach development in ruminants was done in the late 1950s and early 1960s (Tamate et al 1962; Warner and Flatt 1965). However, it focused mainly on cattle and sheep, with little research was outside of these species. From the information available there is a positive relationship between the length of the gestation period and the time required for stomach development (Church 1975). Simply put, ruminants with shorter gestation periods like sheep require shorter periods of time to reach full stomach development as compared to ruminants that have long gestation periods like cattle. However, as much as gestation length can influence stomach development so too does the nursing period.

2.4 Factors affecting stomach development

When a calf is born it is to all intents and purposes a monogastric and does not have a functional rumen. The rumen is present but is very small. While the calf is nursing from the cow and consuming primarily milk, the rumen does not develop very quickly. The milk, for the most part, is shuttled past the reticulo-rumen into the abomasum and on down the digestive system. This shuttling continues even as the calf grows and the rumen develops. The nursing effect of the calf creates what is referred to as an esophageal groove that acts like an extension of the esophagus, helping the milk by-pass the first stomach compartments and the digestive activities contained within. This helps the milk to be digested in a more complete form farther down the digestive tract (Church 1975).

It was long presumed that normal development of the stomach was an orderly process mediated by the endocrine glands. At a given age and weight and when an animal was on a roughage diet, the approximate relative development of the stomachs could be predicted with reasonable accuracy. However, after considerable research in the late

1950's and early 1960's (Loe et al. 1959; Neidermeier et al. 1959; Warner and Flatt 1965) other factors were found to have a greater influence on stomach development than age and weight of the animal.

One of the early experiments that emphasized that there were factors other than age and weight at play in controlling stomach development was work that restricted young ruminants to a liquid diet of milk or milk replacer. In those experiments researchers were able to delay the development of the reticulo-rumen. They also found that reticulo-rumens of these animals had thinner walls, lower capacity, lacked normal development and coloration of papillae compared to the same aged animal that were on a roughage based diet (Loe et al. 1959; Neidermeier et al. 1959; Warner and Flatt 1965; Church 1975). Harrison et al. (1960) reported that rumen papillae regress in size and number when an animal is changed from a grain-hay diet back to a milk diet. Church (1975) reported that some regression in rumen papillae occurs after birth and probably continues until the consumption of roughage begins. In the dairy industry, calves are weaned from the cow at birth, and from milk replacer as young as eight weeks (very-early-weaning). Young dairy calves are offered free choice hay and high-concentrate grain from the day of birth on; perhaps these feeds prevent and/or stop any papillae regression if Church's theory holds true. Evidence is available from experimental studies that show that ingestion of roughages is stimulatory to development of the reticulo-rumen in terms of weight and thickness of the tissues and the development of normal papillae (Warner and Flatt 1965). Concentrates may, however result in greater stimulation of papillae in early life than will roughage (Harrison et al. 1960; Stobo et al. 1966; Peron 1970; Church 1975). In beef calves suckling their dams, it has been shown that little rumen development occurred by nine weeks of age (Stewart, 1971), as indicated by rumen weight, papillary development, and rumen contents. Stewart's theory may hold true depending upon circumstances; should the dam's milk production be limited the calf would be forced to find feed elsewhere, mainly grazed forages, this grazing would then result in accelerated papillae development.

The stimulus of roughages and concentrates on papillae development was first thought of as a bulk theory. In other words, the physical contact of these feeds with the rumen walls stimulated papillae development; this theory was studied by Flatt et al. (1958). In these experiments, rumen papillary development was relatively normal when salts from volatile fatty acids (VFA) were introduced into rumen-fistulated milk-fed calves. Plastic sponges inserted into the control animals to add bulk density were ineffective in stimulating rumen development. Therefore at least part of the stimulus for the development of papillae is the presence of organic VFA found in the rumen of adult animals. In other words, feed is ingested and at some point in time there are enough ruminal microflora present to allow fermentation to start, which then causes the release of VFAs. Roughages and concentrates differ in their production capabilities and ratios of the specific VFAs; acetate, butyrate, propionic, and valerate. Warner and Flatt (1965) found that butyrate was more effective than propionate, followed by acetate in stimulating the development of rumen papillae. The difference in VFA production capabilities may be the reason why concentrates stimulate more papillae development than roughages; due to their higher potential for butyrate and propionate production (Harrison et al.1960; Stobo et al. 1966; Peron 1970; Church 1975; Lane et al. 2000).

Another method for changing the VFA production potential would be feeding ionophores like monensin or lasalocid. Randel (1990) found that propionate levels could be altered by feeding monensin; feeding monensin should then also prove positive for enhancing the development of ruminal papillae. Candau (1971) found that ammonia also worked as a stimulant to papillae development. This solution, however, leads to another question – 'to get VFAs and ammonia there needs to be fermentation, to get fermentation there needs to be an inoculated rumen – which comes first?'

2.5 Digestive system inoculation

Young ruminants probably acquire rumen bacteria mainly through feed and interanimal contact (Van Soest 1997). Anaerobic bacteria similar to those found in the rumen occur in nature, particularly in manure and soil. Despite the sensitivity of many rumen organisms to temperature and oxygen, they can be transferred via saliva and feed from one animal to another and escape down to the digestive tract. Inoculation probably depends on the survival of only a few cells; this theorized the concept of rumen inoculation as a method of hastening rumen development. However, no consistent advantage of inoculation has ever been established (Van Soest 1997).

Rumen populations tend to be similar in animals on a given diet, although many of these microbial species may occur in relatively small numbers, and any of these may respond to a dietary change. Existing bacteria can adapt or mutate to accommodate a new substrate and changes in rumen conditions. The normal adaptation period is about one to two weeks. For example, in the case of an abrupt dietary change from hay to concentrate, rumen adjustment is facilitated by inoculation with rumen contents from an animal already on the new diet. Early-weaning of beef calves clearly results in an abrupt change of the diet for that calf. The abruptness and severity of the diet change to the calf will depend on the calf's age, milk production of the dam and the feed resources that the calf had been exposed too. Perhaps this may suggest that another management technique for early-weaning calves is to use older animals not just as a trainer but to somehow also facilitate inoculation of the digestive flora through direct contact (Church 1975).

2.6 Early-weaning and sexual development

Next to winter feed costs, reproduction ranks as one of the most important factors affecting ranching productivity and profitability (Bellows et al. 1974; AAFRD 1999). The ability of a heifer to breed by 14 months, calve by her second birthday and keep this routine on a 365 day cycle is vital for a profitable beef enterprise (AAFRD 1999).

Richardson et al. (1978) studied the reproductive and progeny performances of 458 Angus heifer calves over a six-year period that were either weaned at 120 days or 210 days. He reported that there were no differences in sexual development in either treatment and that the early-weaned calves in this trial were 10.1 kg heavier than normal-weaned calves at 210 days. Early-weaned heifers also exceeded late-weaned calves in conformation. The reproductive and maternal performance of heifers as they moved into the cow herd was also studied (Table 2.4).

Table 2.4 The reproductive and progeny performance classified by the age at which the cow was weaned as a calf (Richardson et al. 1978).

	Cow Weaning Age			
	120 days		210 days	
Trait	Mean	SE	Mean	SE
Pregnancy rate %	85.6	3.0	85.1	2.8
Calving date	92.1	1.7	91.2	1.7
Live calf, %	79.5	3.2	75.8	3.4
Calving Difficulty	1.08	0.04	1.07	0.04

Richardson et al. (1978) found that early-weaned heifers had slightly better but not significantly different pregnancy rate (0.5%) but no differences in cyclicity and/or services to first conception. There was also no difference in calving difficulty between the two groups. The difference in the percent of live calves weaned was almost 5% in favour of early-weaned dams, however due to the large standard errors, it was not significant (P>0.05). To ensure adequate conception rates British type heifers need to be 65% and Continental type heifers 70% of their mature weight at 15 months of age Patterson et al. (2002).

Weaning age of the cow was not a significant factor affecting the subsequent birth weight of her calves over the six-year experiment. However, in the second parity early-weaned cows had calves that were 2 kg heavier (P<0.05) than those from late-weaned cows. Calfhood pre-weaning treatment of the cow by sex of calf interaction was significant (P<0.10) for birth weight. Both male and female calves from early weaned cows were slightly heavier at birth but by 120 and 210 days there were no differences.

Grimes and Turner (1991b) studied the effects of early-weaning (110 day) vs normal-weaning (220 day) on 152 fall calving cows over a five-year period in Ohio. The results were similar to Richardson et al. (1978). No differences in reproductive performance of heifer calves weaned at either 110 or 220 days were noted over the five-year study.

The effects of early weaning on the fertility of early weaned heifer calves, have been mixed. Boadi and Price (1993) found that early weaned heifers reached puberty 25 days later on average than calves that were normally weaned. They attributed the differences in puberty to the lower live BW of the EW weaned calves compared to the NW calves at the start of breeding. All heifers were on a restricted diet during the backgrounding period, which hindered compensatory gain.

2.7 Early-weaning and managing weaning stress

Forced weaning is a distressing experience for most animals, especially if performed before weaning would occur naturally (Houpt 1991). In wapiti calves it is considered stressful as evidenced by sharply reduced lymphocyte counts following separation from the dam, fawns can then be more susceptible to disease, and often pace the fencelines (Griffin et al. 1988; Pollard et al. 1992).

Two physiological forces governing behaviour at weaning include the filial/maternal bond and social facilitation with other members of the herd (Houpt 1991). Usually "social facilitation" is a term applied to the phenomenon in which the mere presence or behaviour of another organism produces an increase in the probability, rate, or frequency of a behavioural pattern in another organism (Dewsbury 1978). However, Zajonc (1965) found that the presence of another animal can result in an interference with performance of a behaviour rather than facilitation of it. Therefore, the presence of conspecifics may be utilized as a management tool to prevent undesirable behaviour. When a calf's dam is removed, the filial/maternal bond is broken and the separation is distressing to both the cow and calf. But while interval-weaned (weaning groups of calves in stages) calves may have suffered anxiety by removal of their dam, the presence of conspecifics appears to have dampened the effect. Conversely, abrupt-weaned calves experienced the distressing separation of their dams simultaneously, and hence the stress of removal of the dam appears to be exacerbated by social facilitation. Church (1997) recommended interval-weaning on welfare grounds if not productivity. Fence line weaning would cause similar behavioural reactions as observed in interval-weaning.

Church (1997) also studied the effects of abrupt vs. interval-weaning on behaviour, weight gain and neutrophil/lymphocyte ratios of beef calves. One hundred calves (180 d; 218 kg) were either abruptly-weaned or interval-weaned. Immediately following weaning of calves in the interval group, all of the calves were relocated to feeding pens and fed ad libitum and observed for behavioural changes. Interval-weaned calves gained more weight than abrupt-weaned calves during the first week; the reverse was true during the second week. At the end of the 28d feeding period, there were no significant ($P>0.10$) differences between abrupt and interval-weaned calves for ADG.

Interval-weaned calves spent less time standing and pacing and more time eating compared to abrupt-weaned calves. Neutrophil/lymphocyte ratios were greater in the abrupt-weaned calves compared to the interval-weaned calves (0.81 vs. 0.51; $P<0.05$). In addition, the ratios were also considerably higher in male calves than female calves. There was no difference ($P>0.10$) in morbidity between the treatments. Church (1997) concluded that the behavioural observations of abrupt and interval-weaned calves indicate that the different weaning management regimes can cause behavioural differences.

Very-early-weaning (<60 d) is considered standard practice and easier to manage in the dairy industry because calves are removed from their dams at birth and introduced to new feeds. In the beef industry weaning is trickier because of the naiveté that calves may have to new feeds. This naiveté often means that calves will not feed or drink water properly for several days following weaning. This can make them more prone to respiratory diseases and cause higher rates of morbidity and mortality (Fluharty et al. 1996).

Creep feeding is a management option that can allow a calf to become accustomed to a new feed source, thereby reducing the calf's naiveté to it. It helps to reduce the amount of time that it takes to get the animal back on feed following the weaning process. In an example of the impact of creep feeding, Table 2.5 shows the two-year health summary of steers weaned under three management systems; early weaning (EW), normal-weaning with creep feeding (NWC) and normal weaning (NW). Early-weaned steers had a 91% lower respiratory morbidity (P=0.001) compared with the average of NWC and NW steers, and NWC steers had 84% lower respiratory morbidity (P=0.0001) than NW steers (Myers et al.1999). The author concluded that the high percentage of treatment of NW steers could have been attributed to weather effects and lack of prior consumption of a high-concentrate diet. This lack of feed consumption coupled with weather changes (i.e. cold wet weather in the fall) and a break with the filial/maternal bond may have been enough to induce the respiratory morbidity seen in this experiment.

Table 2.5 Health of steers as affected by three weaning management systems (Myers et al. 1999a).

	Treatments			
Item	EW	NWC	NW	SEM
Respiratory Morbidity %	1.2	3.6	22.8	3.1
Digestive Morbidity %	1.2	0	0	.7
Digestive Mortality %	1.2	0	0	.6
Accidental Mortality %	1.2	1.2	0	1.0

Another management system for dealing with the naiveté of weaned calves has been the use of trainer animals. Fluharty et al. (1996) studied the effects of trainer animals on the performance of newly weaned calves after arrival at the feedlot. Six mature cows and six mature steers were used in the study as babysitter animals to examine the performance and morbidity of freshly weaned calves. On day one, more (P<0.05) calves in the cow group (81.7%) were observed eating compared with either the steer trainer group (60%) or the control group containing no trainer animals (48.3%). Furthermore, newly arrived calves in both the cow and steer trainer groups consumed more daily meals (P<0.05) compared with the control group (1.4 and 1.5, vs. 0.9, respectively). On day two, more (P<0.05) calves were observed eating in both the cow and steer trainer groups compared with the control group (68.3% and 63.3%, vs. 38.3%, respectively). From days three to seven there were no longer any differences (P>0.10) in the percentage of calves eating between the cow trainer group and control group. Although the calves from both trainer groups consumed more meals and were observed eating more times than control calves, there were no differences (P>0.10) in animal performance over the 28 day feeding period. There were also no differences (P>0.10) in morbidity due to trainer animals. The authors concluded that calves without trainers compensated for any decrease in ADG early in the receiving period by having an increased ADG in the subsequent weeks.

All of the previously mentioned stress/weaning practices have been shown as effective management practices for dealing with weaned calves. Another practice that has helped in preventing stress related disease like shipping fever has been calfhood vaccination. In a New Mexico weaning study, Parker (1993) studied the effects of vaccination at two months of age on serum titre levels. At the time of spring processing, serum titre levels greater than 1:4 for IBR, BVD, PI3, and BRSV infection were found in 35%, 65%, 98%, and 71% of calves, respectively. In this trial half of the calves were vaccinated at spring processing and then revaccinated at weaning, whereas the remaining calves were vaccinated twice, only at weaning. By 28 days postweaning, 81% of the calves vaccinated at branding and 63% of the calves vaccinated only at weaning had shown a positive response to the feedlot vaccination. The study revealed that vaccinating pre weaning, even when calves are carrying passively acquired antibodies, tended to produce increased antibody responses to those viral antigens when the calves were revaccinated on arrival in the feedlot.

2.8 Early-weaning and its effects on feedlot finishing and carcass quality

The definitions of carcass quality are as diverse as the management practices used in the cow/calf industry. Increasingly, carcass quality as defined within the North American context refers to the carcass yield grade, marbling score, carcass conformation, fat colour and texture as the method for rating the merits of one carcass over another (Myers 1999c). Within the confines of a value-based marketing system, the competitive ability of beef could be enhanced by raising cattle that produce high yielding and highly marbled beef in a shorter period of time.

Traditional management of early-weaning beef calves often requires that there be a higher level of management and feeding. Most early-weaning research (Lusby et al. 1990; Fluharty et al. 1997; Myers et al. 1999) has shown that the best performance (average daily gain and feed:gain) occurred with calves that are fed high-concentrate rather than high-roughage diets. Reasons for the improved performance of calves fed high-concentrate diets are many, and include: improved papillae growth brought on by the changes in VFA ratios (Warner and Flatt 1965), increased energy densities of ingested feed (Fluharty et al.1997), and a decreased need for additional rumen capacity (Myers et al. 1999). Early weaned calves placed on high-concentrate diets after weaning have had greater gain, lower intakes, better feed:gain ratios and were younger at slaughter.

Myers et al. (1999) examined three weaning scenarios in spring-born beef calves. Steer calves were either 1) early-weaned (170 d) and placed on a finishing diet (EW), 2) creep fed for the last 55 days on pasture prior to weaning and then placed on a finishing diet (NWC), or 3) normal weaned and then placed on a finishing diet (NW). They found that EW steers had lower intakes (7.70 vs. 8.16 kg/d, P=0.008) and better gain:feed conversions (0.170 vs 0.153, P=0.002) than the average of NWC and NW steers. However using USDA standard quality grading techniques the responses of treatments were mixed (Table 2.6).

Table 2.6 Effects of three weaning management systems on carcass quality (Myers et al. 1999).

Item	Treatments[1]				Contrast	
	EW	NWC	NW	SEM	EW vs NWC & NW	NWC vs NW
Carcass weight	283	276	272	4	.04	.42
Est. KPH%[2]	2.3	2.2	1.9	.1	.0005	.001
Avg. Yield Grade[2]	2.71	2.67	2.57	.04	.03	.03
Yield Grade 1, %	12	5	16	4	.70	.02
Yield Grade 2, %	49	66	57	7	.13	.23
Yield Grade 3, %	39	29	27	5	.07	.83
Choice, %	95	87	91	4	.16	.39
Average, Choice %	81	58	58	6	.003	.99
Prime, %	15	10	2	4	.06	.15

[1] EW= early weaned (170 d); NWC = normal weaned creep (225 d); NW = normal wean (225 d)
[2] Estimated kidney pelvic and heart fat

The EW steers had a 9-kg heavier carcass (P=0.04), however there were no differences between the NWC and NW calves. The EW steers had 12% more kidney, pelvic, and heart fat (P=0.0005) than the average of NWC and NW steers, and NWC steers had 16% more (P=0.001) than the NW steers. The differences in kidney, pelvic, and heart fat are reflected in differences in yield grades. The NW calves had a significantly (P=0.02) greater yield grade than EW and NWC. Conversely, EW improved the percentage of steers grading Average Choice or higher by 40% (P=0.003) over the average of NWC and NW treatments. The EW improved (P=0.06) the percentage of steers grading Prime or higher by 150% over the average of NWC and NW.

The results between NWC and NC were opposite to the results found by Deutscher and Style (1978) and Faulkner et al. (1994), who observed an improvement in quality grade for creep-fed calves compared with controls. Myers et al. (1999) concluded that the NWC steers were slower getting started on the creep and they were fed for a shorter period of time than Faulkner et al. (1994).

Similar results of high marbling scores and low yield grades on early-weaned calves (110-d) were found by Fluharty et al. (1996). They concluded that early-weaning of calves onto a 100% concentrate diet might cause problems late in the feeding period. Steers that were fed a 100% concentrate at either 12% or 16% CP had back fat measurements of 17 and 16.5 mm respectively and grades of 4.2 (scale 1 to 5). They also concluded that these back fat and yield grade values may be unacceptable to the beef industry and that evaluating the calves for breed type, frame score and perhaps using a more aggressive implant program may be warranted with early-weaned calves fed high-concentrate diets.

The differences in body fat content and subsequent carcass yield of early-weaned, normal-weaned and creep-fed animals may partially be explained by another study from Myers et al. (1999c). They compared the visceral and digestive tract weights of early-weaned steers receiving a high concentrate diet or grown on pasture before finishing. They found that pasture steers tended (P=0.15) to have larger liver weights and a 14% larger (P=0.01) rumen weight than steers fed a high concentrate diet. Myers et al. (1999c) concluded that these organs have higher energy requirements per unit of mass than the body average. In other words when feed intake increases, hypertrophy occurs in the organs that have greater energy expenditures per unit of weight. Daily energy intake may be similar for both treatments, but because the early-weaned calves on a high concentrate diet had lower energy requirement for gut maintenance due to a lower gut weight more energy could be partitioned to fat deposition and growth.

Although early-weaning shows significant advantages on the feeding side of the equation; there is limited information available on the affects of carcass quality. Regarding the goals for the finished carcass: high marbling or high yield, it is difficult to have both. Placing early-weaned calves on feed would need careful consideration in order to achieve both the desired carcass traits and feeding efficiencies. Aggressive implants such as a TBA maybe needed as part of the finishing program.

2.9 Summary and conclusion

Altering the age at which calves are weaned is a viable management tool that exists for improving profitability and cutting expenses for cow/calf operations during periods of drought, reduced feed quality and (or) poor conditioned dams. The cow however is only one part of the equation and consideration needs to be given to the management of the calf.

Research in the management of very early weaned dairy calves has helped to create a better understanding of how the digestive system changes and evolves as the animal grows older. The very early weaning principles from the dairy industry hold true to beef calves, however much of the difference in the immediate post weaning performance and growth rates can be attributed to differences in naiveté of the calves. Very early weaned of beef calves (<90 days) will require a higher level of nutritional and herd management than older weaned calves (>90days). Therefore this weaning practice should be reserved only in cases of extreme drought where conception rates could be jeopardized due to high lactational demands, exceptionally poor pasture quality and quantity, and low-body condition. Another opportunity that exists for very early weaning would be in the case of weaning cull cows so that cow/calf operations could take advantage of seasonal variations in cull cow values. Weaning in either situation provides a way to decrease grazing pressure and reduce the energy demands by 15 to 20% as compared to cows nursing calves.

The considerations of whether to early-wean (<100 days) beef calves are many. Many studies have shown that early-weaning does not have any negative effects compared to normal (205-210 d) weaning, and often the EW calves have better pre and post-weaning feed efficiencies, ADG and morbidity rates than normal-weaned calves. By weaning at this age, not only are the management related issues pertaining to the calves reduced but there is also opportunity for the cows to gain body condition prior to the wintering period which would help stretch fall grazing resources because of the reduced dry matter consumption. Waiting till the nursing calf is a little older, which means the digestive system is more developed, will also help to ease producer concerns about the management of early weaned calves.

When planning any type of weaning strategy, particularly for younger calves (<120 days), keeping the hay content low, and keeping the concentrate, protein and palatability levels high is very important. Volatile fatty acid production is an important stimulus for accelerating rumen and gut development, and having a ration that increases the ratios of propionate and butyrate will help this process.

Animal behaviour and management is also important. Any method of settling calves, reducing their naiveté, bunk breaking and (or) pre-immunization will help to improve overall calf performance, morbidity and mortality rates. Consumption of feed in the first four to five days should be high at 3 to 3.5% of body weight. After about 30 days, moving the calves to high quality forage or pasture could be an option, or depending on the age of the calves, type and (or) growth potential, they could be put on a finishing diet. However, consideration of the feeding program and the effects of the diet on animal finishing and carcass characteristics of the animal must also be taken. With heifers the research results have been mixed as to whether early-weaning negatively affects reproductive and sexual development. Closer scrutiny of the literature would indicate that post weaning live body weight gain would have some role in affecting the age of first estrus in the early weaned heifer. If heifers are kept on a low energy diet and have low live weight gains (<0.75 kg /hd/day) from the time of weaning to the time of breeding there would more than likely be reduced conception rates.

This chapter has outlined many of the production aspects that need consideration when weaning calves. Most of the literature presented has focused on segments of the cow/calf operation that would be affected by weaning rather than the whole system. Little information has been published about long-term implications of a very early and early weaning management plan. For these alternative weaning practices to gain acceptance by the cow/calf industry, a long-term study over several years needs to be looked at.

A long term study would help sort out year to year variations in factors like animal performance, forage quality and weather. As stated by many previous researchers (Lusby et al. 1981; Peterson et al. 1987; Story et al. 2000) retained ownership should be part of the overall management plan of early and very early weaned animals. Although lighter weaned calves are often priced higher than heavier weaned calves their lower body weight would reduce total gross sales for the cow/calf operation if the calf were sold early on. The approach of retained ownership using management recommendations such as aggressive implant programs for these calves would help to better answer the question of how to incorporate alternative weaning into a cow/calf production system. It would also give another opportunity to study the effect of weaning on the sexual development of early weaned heifers fed a low energy diet post weaning. Incorporating these ideas is the basis for the three year biological study that will be presented in the next chapter and the economic results that are presented in Chapter 5.

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CHAPTER 3

THE EFFECTS OF AGE OF CALF AT WEANING ON COW AND CALF PERFORMANCE IN A SPRING-CALVING BEEF HERD

3.1 Introduction

Altering calving and weaning dates can influence herd performance (Lusby et al. 1981; Adams et al. 1994; Whittier 1995; Grings et al. 2005) for North American cow/calf producers. An increase in net returns may be realized by greater herd reproductive performance, improved calf performance and alternative marketing options when either the calving or weaning date is changed (Lusby et al. 1981; Whittier 1995; Meyers et al. 1999b; Meyer et al. 2005). Maintaining or improving cow body weight and condition, as well as calf gain in the face of declining forage quality and quantity during the fall, is a problem for most cow/calf producers. Efficiency in a cow/calf operation is a function of inputs and outputs and both must be measured in order to assess the treatment effects on efficiency. The production efficiency in a cow/calf production unit is a function of weaning weight, cow BW and BCS, rebreeding success and the number of calves weaned (Wiltbank 1994; Grings et al. 2005).

Early weaning (Peterson et al. 1987; Myers et al. 1999a) at 150 days of age has shown promise as a means of increasing calf growth by better matching the nutritional needs of the calf as compared to the calf nursing the cow. Green and Buric (1953) concluded that 90-d weaning did not adversely affect beef calves, and the main difference between 90- and 180-d weaned groups was in early post weaning rate of gain. In cows BW and BCS are the primary measures of nutritional status and have the greatest control on reproductive potential and feeding flexibility over the winter months (Short et al.

1990). Production efficiency can be enhanced by optimizing the BW and BCS of cows through manipulation of the weaning period. Likewise, calf performance can be enhanced and morbidity and mortality reduced through changes in weaning time. Several workers have evaluated cow and calf performance when weaning takes place at 150 d of age (Peterson et al. 1987; Gill et al. 1993; Purvis et al. 1996; Grings et al. 2005). Economic modeling of spring calving cow/calf enterprises in the mid west United States (Spreen and Laughlin 1986) indicated that weaning calves at six months of age resulted in the greatest net return compared to weaning at four months and eight months of age. However there is limited published data that evaluates the long-term implications of early weaning on cow retention rates and reproductive performance. Meanwhile many of the weaning studies (Lusby et al. 1981; Whittier 1995; Meyers et al. 1999b; Meyer et al. 2005) that have looked at post weaning calf growth rates, finishing characteristics and heifer calf sexual development have been one year studies when multi-year experiments are needed. The objectives of this study were to evaluate the long term effects of weaning calves at 72, 132, or 192 d of age on subsequent cow and calf performance and factors that influence the net income and decision making process for cow/calf operators contemplating the manipulation of weaning times as a management tool in a spring calving cow herd.

The null hypothesis for this research was that the performance of cows (BW and BCS) and calves under a very early weaning (VEW; 72d) and early weaning (EW; 132d) management system would not differ from those of cows and calves under a normal weaning (NW; 192d) system.

3.2 Materials and methods

3.2.1 Cows

This study was conducted at the University of Alberta Kinsella Research Station located in East Central Alberta, from March 30, 1998 to March 30, 2001. Two hundred and forty Kinsella Beef Synthetic (Berg et al. 1986) Spring (April / May) calving cows (BW ± SD: 605±8 kg; BCS ± SD: 2.6±0.06 at March 30, 1998), were assigned to one of three weaning management groups based on BW, BCS and age (young: 4 and 5 years of age; medium: 6 and 7 years of age; old: 8 and 9 years of age). The three weaning treatments were:

- very early weaned (**VEW** age ± SD: 72±12 d age; n =96; weaned approximately July 9)
- early weaned (**EW** age ± SD: 132±12 d age; n =92; approximately September 9),
- normal weaned (**NW** age ± SD: 193±12 d age; n =50; approximately November 9).

Cows remained in their assigned weaning treatments for the three years unless culled from the herd for reproductive failure, poor feet, poor udder scores and (or) loss of calf. After the normal weaning each year, cows were managed as a group until grazing ceased to be possible and then cows from each weaning treatment were assigned to one of three winter management treatments.

The three winter management treatments were Underfed (**UF** 85% of recommended NRC: NE_M 0.72 Mcal/kg), Normal Fed (**NF** 100% of recommended NRC: NE_M 0.85 Mcal/kg) and Overfed (**OF** 115% of recommended NRC: NE_M 0.98 Mcal/kg). Wintering rations were isonitrogenous, but energy values were adjusted to achieve the recommended NRC energy values for the specific treatment. This was achieved by testing the winter feed stuffs and adjusting the amount of green feed (oat hay) fed to the cows. Cows were fed in open fields from January through to March when grazing became limited. The experiment was a 3 x 3 factorial design. During the spring and summer, all cows were managed as a single group and grazed cool-season native fescue *(Festuca halli* L.) and cool-season tame brome and blue grass *(Bromus inermis* L., *Poa pratensis* L.) pastures. Weaned cows stayed within the main herd until winter-feeding began. The amounts of hay, supplement, and other inputs specifically associated with each weaning management group were recorded. Cows were weighed and body condition scored five times per year; one month prior to calving, at each weaning period (VEW, EW, NW) and just prior to the winter feeding period. Cows that fell below 1.5 body condition score, anytime during the experiment (1 = emaciated, 5 = grossly obese; Lowman et al. 1973) were removed from the trial as culls. Each year during the breeding season, all cows were managed in the same pastures and exposed to Beef Synthetic bulls (Berg et al. 1986) for a 45-d breeding season beginning the day of very early weaning and ending approximately August 23 each year. The bull: cow ratio was 1:25. Calves were identified within 24 hr of birth and weighed with a spring-loaded scale. Calving records were compiled and compared one year to the next to calculate weaning treatment effects on post partum interval (PPI). Cows were scored for ease of calving on a scale of 0 to 5 (0 = no assistance, 1 = slight assistance, 2 = puller used easily, 3 = puller used with difficulty, 4 = veterinarian required and 5 = caesarean birth). Udders were scored (1 = small ideal teats; 2 = ideal teats; 3 = large teats; 4 = very large (bottle) teats; 5 = pendulous udder; 6 = one or two blind teats; 7 = mastitis) within 24 hr after calving. Pregnancy was determined in November by a veterinarian using rectal palpation. No replacements were moved in to replace culled cows. Culling rate was determined as the number of open cows, cows culled for BCS ≤1.5 or loss of calf expressed as a percentage of the total number of cows at the start of the calving season.

Production costs associated with each weaning management group were documented for later economic analysis (Chapter 5).

3.2.2 Calves:

Calves in this experiment were born into one of the three weaning treatments **(VEW, EW** and **NW)** previously described. All cows and calves were managed as a single herd on range until weaned. For two weeks prior to the date of very early weaning, all calves were given access to a creep feeder containing a 20% calf starter (Table 3.1 and Table 3.2). This was done to accustom the calves to a new feed source; thereby reducing the stress of weaning. On the date of VEW each year, all calves and cows were weighed and body condition scored. The VEW calves were removed and transported to a feedlot at the ranch headquarters and the VEW cows and all cows and calves in the EW and NW treatments were returned to native pasture without creep feed. Upon entering the feedlot the VEW calves were given ad libitum access to second cut alfalfa / grass hay and 20% calf starter for the first ten days post weaning. After the 10 day period calves were randomly allocated to either further backgrounding in the feedlot or moved to pasture with free choice access to whole oats creep feed.

The EW calves were weighed and treated in a similar fashion to VEW, except that they were not creep fed prior to weaning. Upon weaning of the final treatment (NW) all calves moved to the next stage of the study. The weaning procedure and dates were approximately the same all three years.

Table 3.1 Composition of starter and backgrounding diets for VEW and EW calves

	20% Calf Starter[a]	Backgrounding Diets Oats Creep	 Second Cut Alfalfa / Brome Hay	 Weaning Pasture
Crude Protein	22.3%	14.2%	14.0%	13.4%
Dry Matter	86.0%	86.0%	85.0%	-
ADF	8.0%	13.3%	37.4%	34.4%
TDN	84.3%	77.3%	61.0%	61.9%
NE_m, Mcal / kg	2.03	1.81	1.34	1.41
NE_g Mcal / kg	1.37	1.11	0.76	0.71
Ca	1.2%	0.08%	1.22%	0.31%
P	0.8%	0.34%	0.19%	0.29%

[a] medicated with 50 mg/kg of decoquinate (Decox)

Table 3.2 Ingredient list for 20% Calf Starter [ab]

Ingredient:	%
Rolled Barley	22.0
Rolled Oats	15.0
Canola Meal	14.4
Rolled Corn	10.0
Soya meal	8.0
Corn Distillers Grain	5.0
Molasses	5.0
Wheat Shorts	4.0
Barley Malt Sprouts	3.6
Bypass Canola	3.0
Calcium Carbonate	1.8
Salt	0.9
Feather meal	0.7
Dicalcium Phosphate	1.2
Corn Gluten Meal	2.8
Calf Micro	1.5
Molasses	0.4
Pellet Binder	0.4
Decox 6%	0.1
Magnesium Oxide	0.2
Anise Flavor	0.1
TOTAL	100

[a] medicated with 50 mg/kg of decoquinate (Decox)

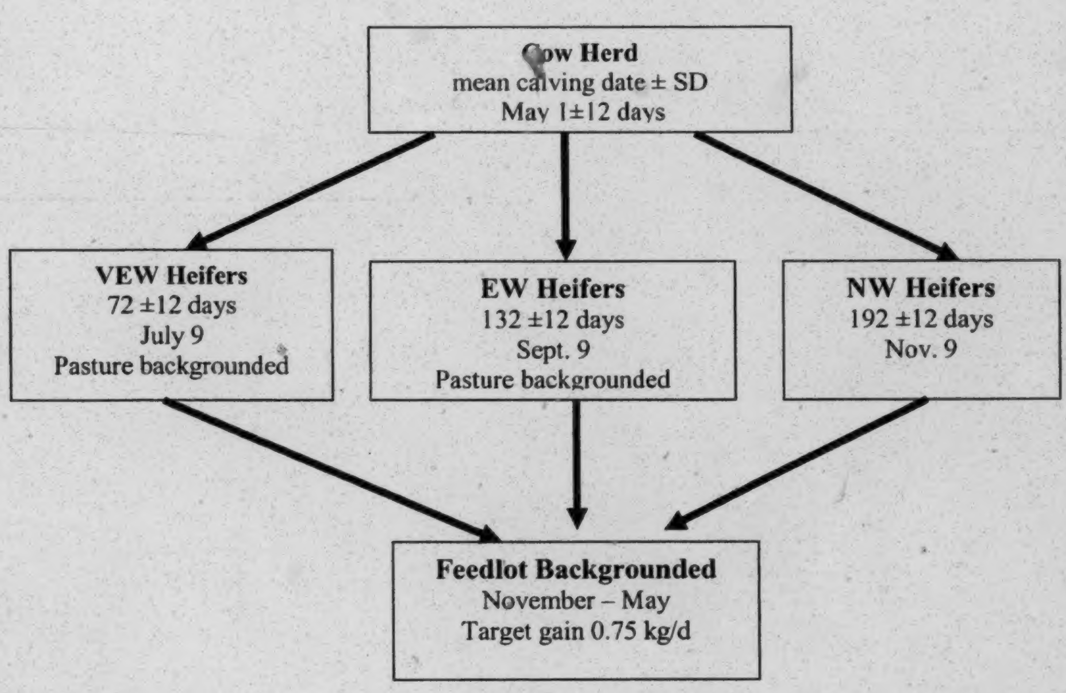
[b] Master Feeds Inc. – Edmonton, Alberta

3.2.3 Heifers

Each year the VEW heifers were held in a feedlot pen for the first 10 days post weaning with ad libitum access to grass hay and 20% calf starter after which they were moved to smooth brome (*Bromus inermis* L.) blue grass (*Poa pratensis* L.) pasture with access to oats creep feed (Table 3.1). The VEW heifers remained on pasture until the last calves were weaned in November (Figure 3.1). Early weaned heifers were held in dry lot for 10 days post weaning after which they were moved to grass pasture; EW heifers also had access to oat creep feed until the NW calves were weaned in November. Upon weaning of the final treatment, all the heifers were gathered, weighed and group fed a grass hay / oats ration (TDN 63%, CP 12%) which provided for approximately 0.75 kg ADG.

Heifers were weighed every 28 d and were evaluated for cyclicity at the end of May. Blood samples were taken 10 d apart by jugular venipuncture and collected into 10 ml heparinized vaccutainers. The samples were centrifuged at 2500 rpm for 15 min at 4°C. Replicate plasma samples were portioned into sterile plastic vials and stored at –20°C for radioimmunoassay. Plasma samples were assayed for progesterone (P_4) using the Coat-A-Count ® Progesterone kit (DPC, Los Angeles, CA). The criterion for identification of estrus was that plasma P_4 concentrations had to be above 1 ng / ml between the two time periods (Boadi and Price 1996). After the May blood sampling and weighing, heifers were either retained as replacements for the Kinsella ranch or were sold; they left the experiment after the May blood sampling.

Figure 3.1 Schematic Outline for Heifers in Experiment


Cow Herd
mean calving date ± SD
May 1±12 days
VEW Heifers
72 ±12 days
July 9
Pasture backgrounded
EW Heifers
132 ±12 days
Sept. 9
Pasture backgrounded
NW Heifers
192 ±12 days
Nov. 9
Feedlot Backgrounded
November – May
Target gain 0.75 kg/d

3.2.4 Steers

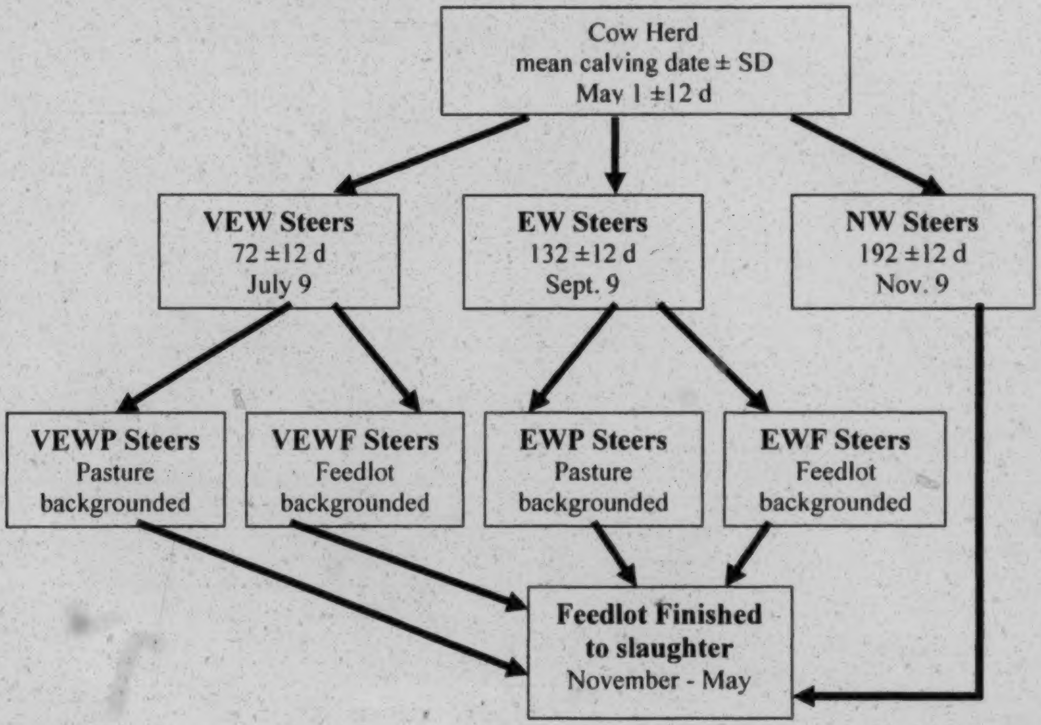
Steer calves assigned to the VEW and EW treatments were randomly allocated to one of two backgrounding systems: pasture or feedlot backgrounding (Figure 3.2). Half of the VEW steers (VEWP) were backgrounded from July to November on Brome / Bluegrass (*Bromus inermis* L./ *Poa pratensis* L.) pasture with access to oats creep feed; the other half (VEWF) were kept in one feedlot pen from July to November with ad libitum access to grass hay and oats. The EW steers were allocated to a similar backgrounding system: pasture with oat creep feed from September to November (EWP), or in the feedlot (EWF) from September to November with ad libitum access to grass hay and oats. When the NW calves were weaned (November 9), the steers from all three weaning treatments were weighed and randomly assigned within treatment to four group feeding pens. In total there were 20 feeding pens; 5 treatments x 4 replications.

Steers were vaccinated with CattleMaster and Ultrabac 7/ Somubac®(Pfizer Inc, New York, NY) for IBR, BVD, BRSV and PI3, treated for internal and external parasites with Dectomax® (Pfizer Inc, New York, NY) and implanted with the growth promoter Component S (Elanco Animal Health, Indianapolis, IN). During the four-week adjustment period to full feed, steers were started on grass hay and fed an increasing amount of a finishing mixed diet consisting of 63% barley, 22% oats, 10% dehydrated alfalfa pellets, and 5% canola meal (TDN 81%, CP 13%). The amount of hay was gradually reduced until the finishing diet, which was offered ad libitum for the remainder of the feeding period, formed 100% of the consumed diet. After 90 d on feed, steers were re-implanted, this time with Component TBA (Elanco Animal Health, Indianapolis, IN).

Steers were fed to an end point where the majority of the pen was visually assessed, by experienced feedlot personnel, to have 1 cm of back fat.

Steers were weighed at birth, at each weaning period and on a 28-d interval during the finishing period. Steer days on feed **(DOF)** and feed to gain ratios (based on a total feed consumption and total weight gain on a per pen basis) **(F/G)** were also calculated. The following carcass traits were recorded by The Canadian Beef Grading Agency: hot carcass weight **(HCW)**, fat depth **(FD)** measured along the edge of longisimuss dorsi muscle between the 12th and13th rib, quality grade **(QG)**, and estimated cutability. Slaughter BW was taken just prior to the animals being loaded for delivery to the abattoir. Cattle were slaughtered at XL Beef in Calgary, Alberta (375 km distance), hauled in 30,000 kg loads and slaughtered off truck. All animals were cared for in accordance with CCAC guidelines for animal care.

Figure 3.2 Schematic Outline for Steers in Experiment


Cow Herd
mean calving date ± SD
May 1 ±12 d
VEW Steers
72 ±12 d
July 9
EW Steers
132 ±12 d
Sept. 9
NW Steers
192 ±12 d
Nov. 9
VEWP Steers
Pasture backgrounded
VEWF Steers
Feedlot backgrounded
EWP Steers
Pasture backgrounded
EWF Steers
Feedlot backgrounded
Feedlot Finished to slaughter
November - May

3.2.5 Pasture and forage quality:

Each year four rumen fistulated Angus cross steers (mean age 3 years; weight 650 kg) were used for the collection of pasture quality information for the cow/calf and weaning pastures (Dubbs et al. 2003). The fistulated steers were used as a method of identifying changes in pasture quality over the growing season, as opposed to clip sampling. Fistulated steers stayed with the herd or in the pasture being tested for a minimum of one week prior to sampling. The steers were gathered in the morning prior to sample collections in the afternoon. Water was available in the pens, but the animals did not have access to feed. Collections were made in the afternoon at 1500 h after complete manual evacuation of rumen contents. Animals were allowed to graze for 30 – 40 minutes, and then gathered for sampling of the rumen contents. Collections were conducted in all the pastures (cow pastures and weaning pastures) monthly from July through to November throughout the grazing season over the three years using the same steers. Rumen samples were dried for 24 hours to constant weight at 45°C and ground through a 3 mm screen before analysis. Analysis of the feed and forage samples for DM, CP, ADF, NDF, TDN, Ca and P were completed in duplicate each year by Norwest labs (Lethbridge, Alberta).

Pasture dry matter availability was determined by clipping 20 cm x 50 cm transects and drying for 24 hours at 45°C. Pasture availability varied from 2500 kg/ha to 4500 kg/ha, depending upon which pastures the cows were grazing. Backgrounding pastures for the weaned calves had pasture dry matter availability in excess of 3500 kg/ha.

Hay, grain and creep feed were randomly sampled at two-weekly intervals. These samples were then compiled for later analysis. DM via the Malt Gravimetric Method (935.29A, 935.29C); CP was done based on: Protein (crude) in Animal Feed, CuSO4/TiO2 Mixed Catalyst Kjeldahl Method, (1990); ADF via: Fiber (Acid Detergent) and Lignin in Animal Feed (1990); NDF based on: Neutral Detergent Fiber – Amylase Procedure (Undersander et al. 1993). Minerals included Ca, P and Na via : Metals in Plants (1990).

3.2.6 Statistical analysis

This study was conducted over a three-year period using repeated measures because of the carry over effects from the previous year's weaning and wintering management assignment. Data were analyzed using the Mixed Model Procedure (SAS Institute, Inc. 1996). Body weight, body condition, birth weights, calving interval and udder scores were subject to an analysis of variance. Calving interval was calculated only for the cows that became pregnant and calved in the following year. Sources of variation were cow age, weaning treatment, year and the interaction of weaning treatment x age. Cows were the experimental unit. Data were analyzed using year x weaning treatment as a random effect. The model statement for analysis of cow body weight and body condition contained the effects of weaning treatment, year, age and all possible first order interactions. Least square means (LSM) were separated using the pdiff option of SAS Institute Inc. (1996) when and only when the F statistic was significant ($P<0.05$).

Cow pregnancy rates were analyzed by comparing weaning treatments with pregnancy rate and cyclicity using PROC FREQ of SAS. Differences in pregnancy rate were compared with Fisher's Exact Test.

The model used for the cows was:

$$Y_{ijk} = \mu + T_i + Y_j + A_k + TY_{ij} + TA_{ik} + E_j\,(_{ijk})$$

where Y_{ijk} = trait under consideration; μ = overall mean; T_i = weaning treatment groups (*i*= VEW, EW, NW); Y_j = year effect (1,2,3 years); A_k = age effect (young; 4 and 5 years of age, medium, 6 and 7 years of age, and old; 8 and 9 years of age) TY_{ij} = treatment x year effect; TA_{ik} = treatment x age effect and $E_j\,(_{ijk})$ = the error term.

Calf performance and carcass data were also subject to an analysis of variance. Sources of variance were year, weaning treatment, backgrounding treatment and all possible two and three-way interactions. Data were analyzed using the animal as the random effect. For the effects of weaning treatment on live weight gains, carcass quality and feed conversion in the steers and first estrus in the heifers, data were analyzed using the Proc Mixed Model of SAS (SAS Institute Inc., 1996). Results from the heifers and steers were analyzed using pooled results from the three-year experiment. There was a year effect however because the experiment started with a new set of calves each year. There was no carryover effect and so data were pooled. The model used for the calves was:

$$Y_{ijk} = \mu + T_i + B_j + TB_{ij} + E_k\,(_{ijk})$$

where Y_{ijk} = trait under consideration; μ = overall pooled mean; T_i = weaning treatment groups with (*i* = VEW, EW, NW); B_j = backgrounding treatment; TB_{ij} = weaning treatment effect x backgrounding treatment and $E_k\,(_{ijk})$ = the error term. Least square means (LSM) were separated using the PDIFF option of SAS (1996) when the F statistic was significant ($P<0.05$).

3.3 Results

3.3.1 Cows:

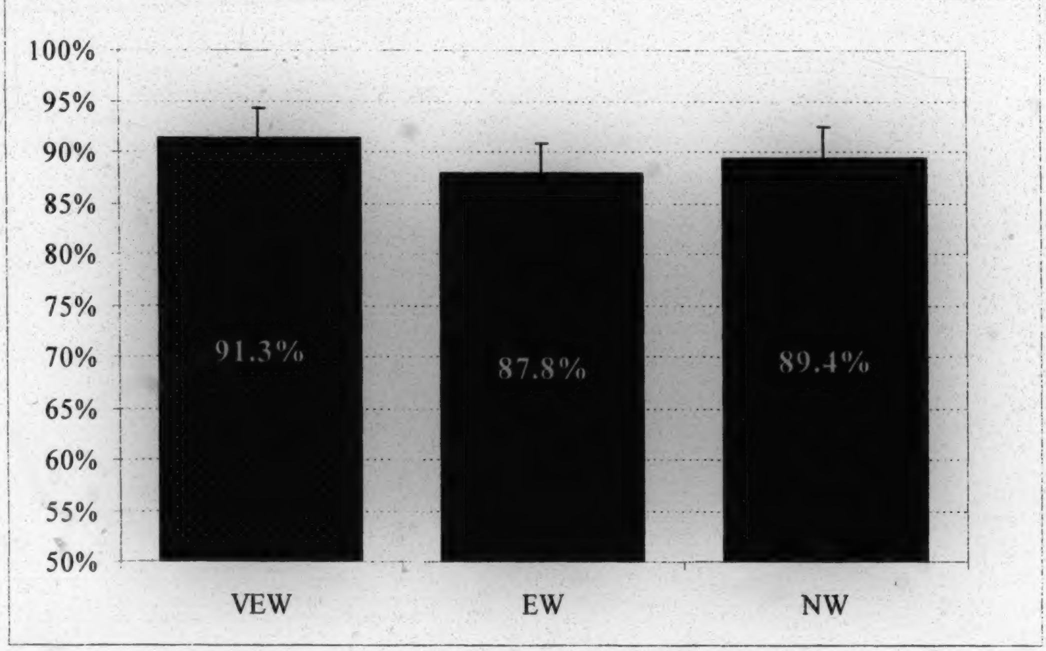
Cows were assigned into three wintering groups: overfed (115% of recommended NRC: NE_M 0.98 Mcal/kg), normal fed (100% of recommended NRC: NE_M 0.85 Mcal/kg) and underfed (85% of recommended NRC: NE_M 0.72 Mcal/kg). This resulted in a 3x3 factorial arrangement for the study. The plan was to study the interaction between weaning treatment and winter energy intake, to see whether earlier weaned (presumed fatter) cows would be less affected by low winter energy levels over the three-year period. Unfortunately, this part of the study was difficult to control. Weather patterns on the research station over the three winters were atypical and varied from excessive wind chill in some pastures to little or no snow in others. A lack of snow cover allowed some cows access to forage aftermath even in the middle of winter, making it impossible to control energy intakes. An example of this was that cows in the underfed group (85% of recommended NRC) refused to eat their ration because they could continue to graze.

In addition there was excessive wind chill exposure (60 km / hr wind coupled with -35°C weather) in some of the pastures, which complicated energy balances to such an extent that the validity of the results were in doubt after statistical prexamination. Because the design of the experiment was factorial and balanced, loss of this part of the study had no effect on the validity of the rest of the study.

3.3.2 Effects of weaning on pregnancy and culling rates of cows.

In the first year after the weaning treatments were applied, pregnancy rates were 93.8%, 91.3% and 86.0% respectively for the VEW, EW and NW treatments (Table 3.3). In the second year pregnancy rates for VEW and EW were slightly reduced and NW increased to 94.1%. In the third year rates were 88.8%, 84.1% and 90.0% for VEW, EW and NW treatments. Pooled results for the experiment over the three-year period were 91.3%, 87.8% and 89.4% for VEW, EW and NW treatments (Figure 3.3). Results indicated no significant (P>0.05) differences in pregnancy rates among treatments.

Figure 3.3 Average pregnancy rates for VEW, EW and NW cows over three years.[1]



[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned

However, due to culling procedures relating to udder scores, body condition and calf death losses at birth or shortly thereafter, this study showed that very early weaning (VEW) resulted in reduced (P<0.05) culling as compared to early weaning (EW) and normal weaning (NW) (Table 3.3). Over the three year period the number of cows culled was 33.0% for the VEW cows; 42.3% for the EW cows and 46% for the NW cows.

Table 3.3 The effect of VEW, EW and NW on the reproductive and culling rates of beef cows over the three year period[1].

	Year 1			Year 2			Year 3		
Treatment	VEW	EW	NW	VEW	EW	NW	VEW	EW	NW
No. of cows, (July)	96	92	50	86	77	34	72	62	30
No. of open cows	6	8	7	8	11	2	8	9	3
Percent pregnant	93.8%	91.3%	86.0%	90.6%	85.7%	94.1%	88.8%	84.1%	90.0%
Culling[2]	4	7	9	6	4	2	0	0	0
Total cows culled [3]	10	15	16	14	15	4	8	9	3
Cull rate[4], %	10.4%	16.3%	14.0%	25%^{a}	20.6%^{a}	40.0%^{b}	33.3%^{a}	42.3%^{b}	46.0%^{b}
Calving interval, d	364±2	368±2	364±2	365±2	363±2	363±3	364±2	366±2	367±3
Calf birth weight, kg	36.3±1.1	36.8±1.1	36.3±1.6	41.4±0.9	41.9±0.9	42.1±1.4	40.3±0.9	42.9±0.9	41.4±1.4
Calf mortality %	1	2	0	1	0	2	1	0	0
Udder score[5]	2.3±0.2	2.2±0.2	2.1±0.2	2.4±0.2	2.3±0.2	2.2±0.2	2.3±0.2	2.2±0.2	2.1±0.2

[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned

[2] Cows culled for emaciation (BCS ≤1.5), high udder score, poor feet, late abortion and/or calf death loss

[3] Total cows culled from the experiment = open cows + culling

[4] Total culled cows (open, culled for BCS or loss of calf) as a percentage of the start number of cows in the first year

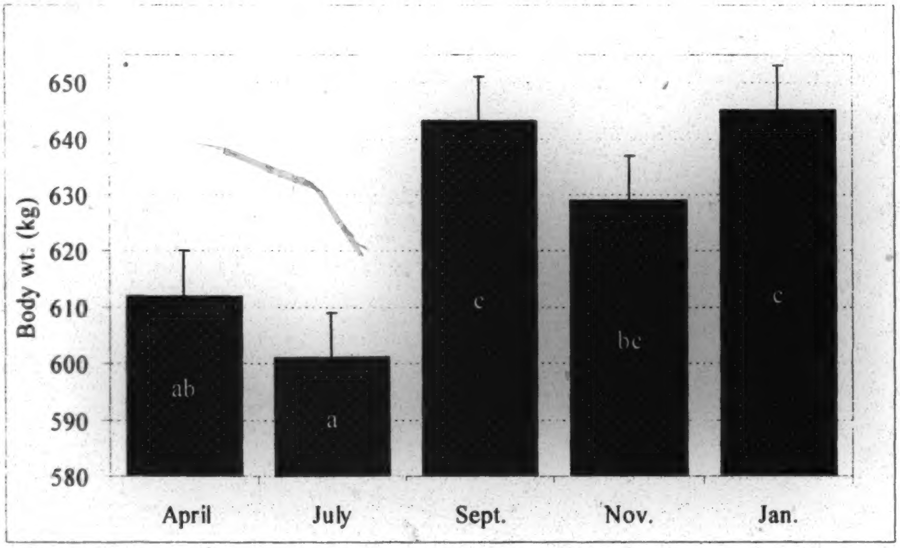
[5] Udder score (1 = small ideal teats; 2 = ideal teats; 3 = large teats; 4 = very large (bottle) teats; 5 = pendulous udder; 6 = one or two blind teats; 7 = mastitis) within 24 hr after calving

[a,b] Means within a row, within a year, with different letters differ ($P<0.05$).

3.3.3 Effects of weaning on body weight and body condition of the cows:

The main effects of weaning treatment, age of dam, time and the interaction of time x weaning treatment and time x cow age were all significant ($P<0.05$) for BW and BCS changes in the cows. The least square means for body weight changes over time are presented in Figure 3.4.

Figure 3.4 Least square means across all weaning treatments for BW x weighing period.

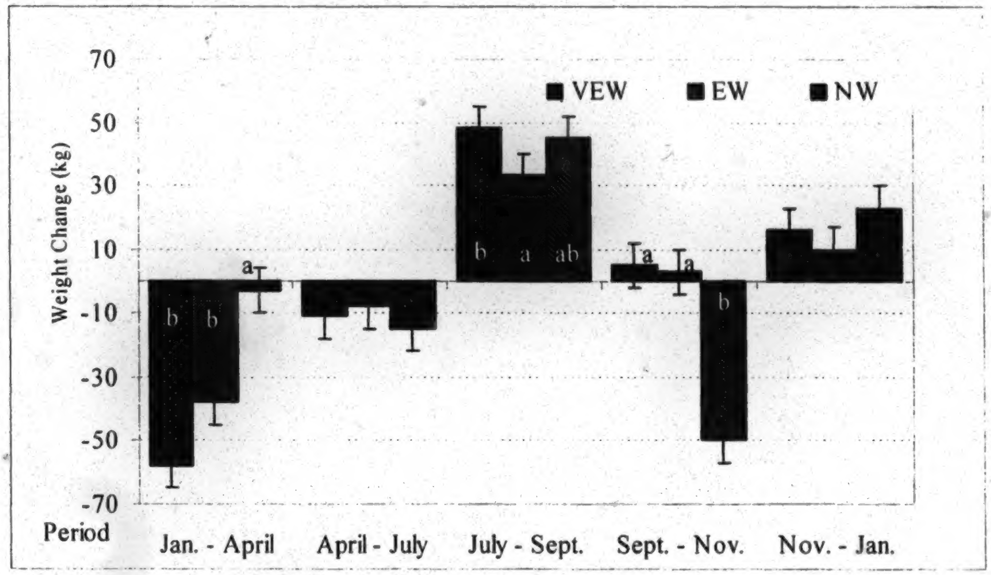


* ^{a,b,c} Columns with different letters differ ($P<0.05$).

Cows across all treatments lost BW from April through to July and then gained through to September. There was a loss of BW for cows from September through to November but by January cows had regained their original September weight.

Analysis of the time by weaning treatment interaction for changes in BW (Figure 3.5) indicated that from April through July cows in all treatments had BW losses. Then from July through to September all weaning treatments gained weight, although the EW treatment had significantly ($P<0.05$) lower weight gains than VEW and NW treatments. The September through to November time period showed that VEW and EW cows gained BW (5.0 ± 6.7 kg and 3.0 ± 7.1 kg) while NW cows had significant ($P<0.05$) BW losses (-50.0 ± 10.3 kg). From November to January all cows gained BW, however NW cows had greater gains than VEW and EW cows. Then from January through to April not only did VEW and EW lose BW but they lost significantly ($P<0.05$) more than the NW treatment which had a marginal change in BW.

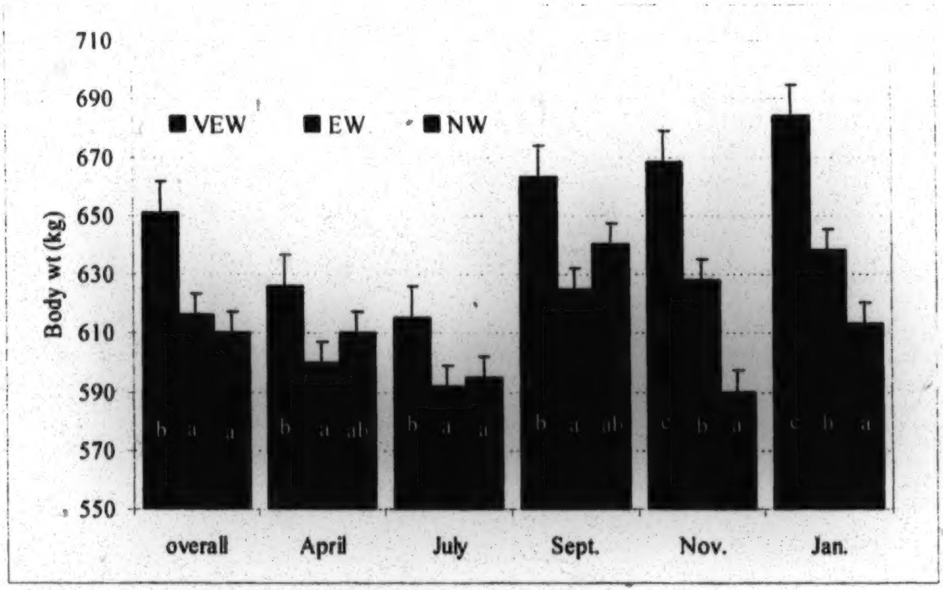
Figure 3.5 Least square mean changes in BW over three years for VEW, EW and NW treatment cows x time period.[1]



* ^{a,b}Columns within groups with different letters differ ($P<0.05$).
[1] VEW: Very Early Wean; EW: Early Wean; NW: Normal Wean

Least square mean values for weaning treatment x time period (Figure 3.6) interaction indicated that the cows on the VEW treatment had significantly ($P<0.05$) heavier BW for all periods than the EW and NW treatments. There were no significant ($P>0.05$) differences in BW between the EW and NW treatments until November. In November the three treatments had significantly ($P<0.05$) different body weight. Those BW differences were still significant ($P<0.05$) amongst all treatments by the time winter feeding began in January.

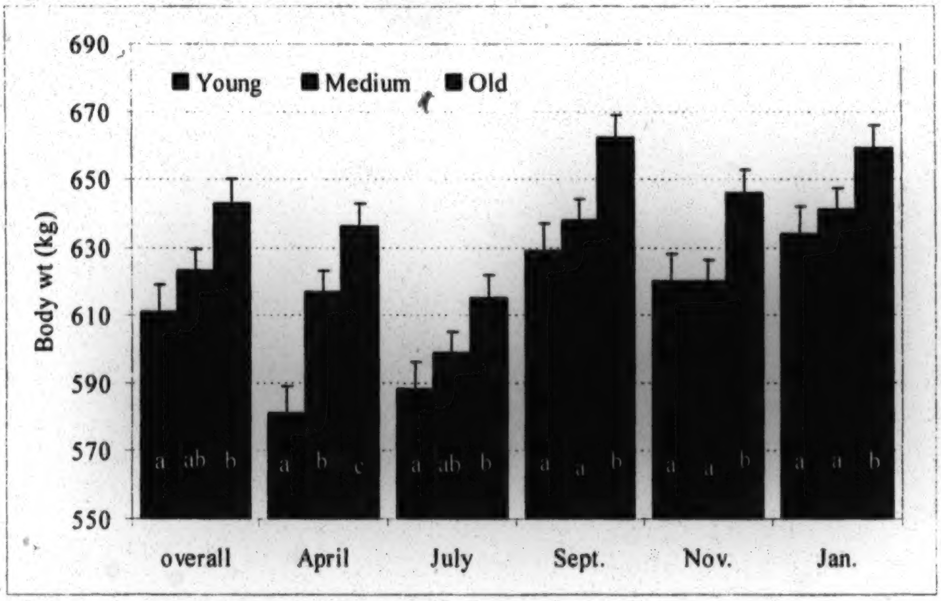
Figure 3.6 Least square mean values for BW over three years: weaning treatment x time.[1]



* ^{a,b} Columns within groups with different letters differ (P<0.05).

[1] VEW: Very Early Wean; EW: Early Wean; NW: Normal Wean

Figure 3.7 Least square mean values for BW over three years: cow age x time.[1]



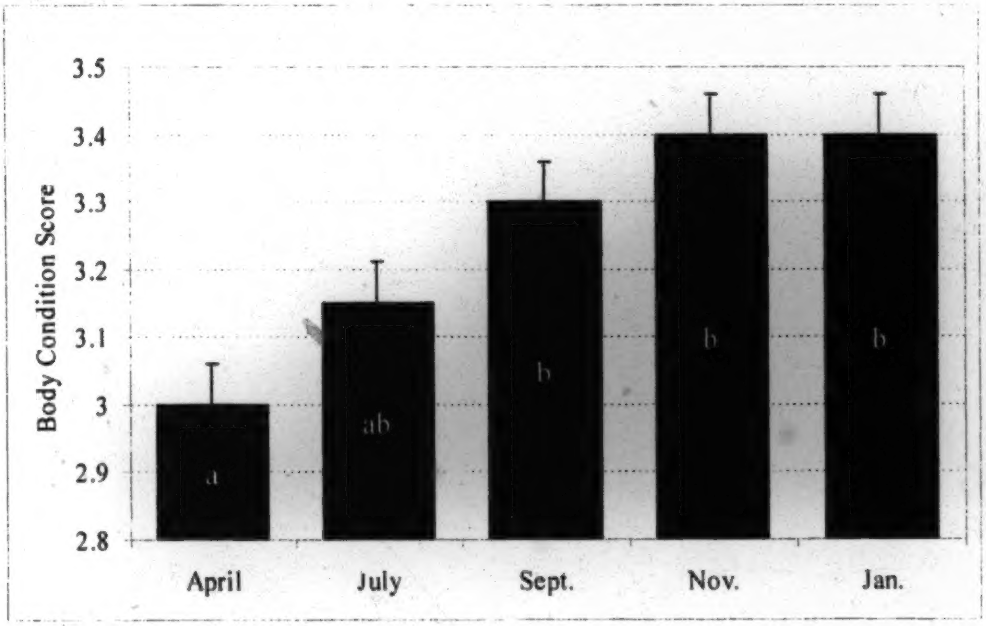
* ^{a,b} Columns within groups with different letters differ (P<0.05).

[1] Young: 4 and 5 years of age; medium: 6 and 7 years of age; old: 8 and 9 years of age

Cow age x time period analysis for BW indicated ($P<0.05$) that older cows were heavier than younger cows for all time periods (Figure 3.7). Young cows were the lightest and medium aged cows intermediate in BW. Analysis also indicated that there were greater swings in BW among young cows than old aged cows; medium aged cows were intermediate.

Time period also significantly affected ($P<0.05$) BCS. From April to January there was a steady increase in the BCS of all treatments and then from January through April a drop (Figure 3.8).

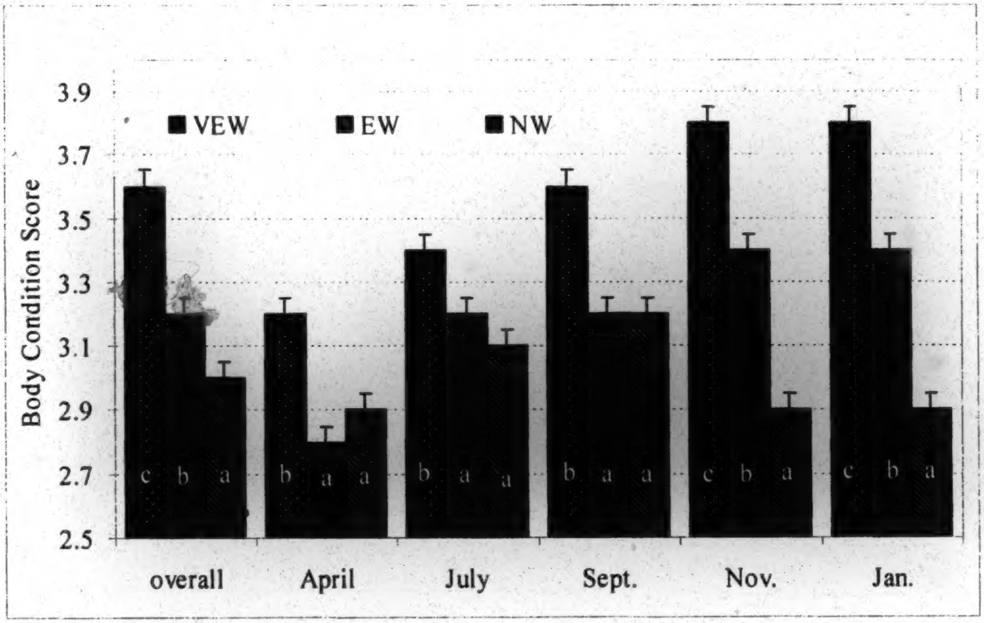
Figure 3.8 Least square means across all weaning treatments and years for BCS x weighing period.



* a,b Columns with different letters differ ($P<0.05$).

Analysis of the weaning treatment x time period interaction for BCS (Figure 3.9) indicated that weaning treatment had a significant overall effect on ($P<0.05$) BCS. VEW cows had significantly ($P<0.05$) greater BC than the EW and NW treatments for the months of April, July and September; there were no significant (P>0.05) differences between EW and NW treatments. However, from September to November, the NW cows lost BC and by November the three treatments had significantly different (P<0.05) BCS. VEW had the greatest BCS, EW was intermediate and NW the least. These BCS remained the unchanged for all treatments through to January.

Figure 3.9 Least square mean values for BCS over three years: weaning treatment x time.[1]

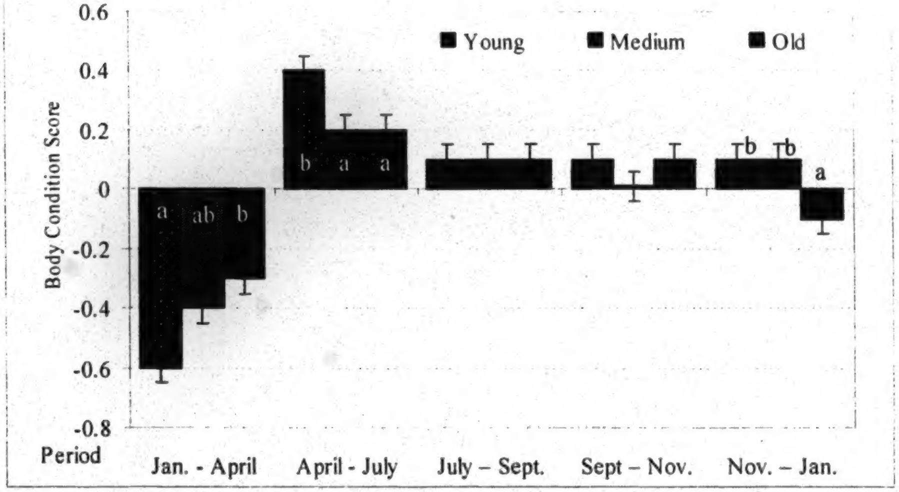


^{a,b,c} Columns within groups with different letters differ (P<0.05).

[1] Young: 4 and 5 years of age; medium: 6 and 7 years of age; old: 8 and 9 years of age

Cow age x time period analysis (Figure 3.10) indicated young cows had greater (P<0.05) changes in BCS than medium and older cows. During the Jan.- April period decreased the most in BCS whereas during the April-July period they had the greatest increase in BCS. These BCS changes represented 1 full BCS on the 1-5 scale, where 1= emaciated and 5 = grossly fat.

Figure 3.10 Least square means changes in BCS over three years: cow age x time period.[1]



* ^{a,b} Columns within groups with different letters differ ($P<0.05$).

[1] Young: 4 and 5 years of age; medium: 6 and 7 years of age; old: 8 and 9 years of age

3.3.4 Heifer growth rates

Analysis of the heifer growth rates showed a year effect. However, each year was independent of the other because the heifers were not retained after backgrounding, so there was no carryover effect; therefore, all the heifer data could be pooled. Neither birth weight nor the weight of the calves at the first weaning period (July) was significantly ($P>0.05$) affected by weaning treatment (Table 3.4). From July to September, VEW heifers gained significantly ($P<0.05$) less than the unweaned heifers. From September to November all treatments had decreased ADG, however the NW treatment continued to have the greatest gains (0.73±0.03 kg/d), followed by the VEW (0.64±0.03 kg/d) and the EW treatment (0.63±0.03 kg/d) (Table 3.4). Average creep feed intake for VEW heifers from July through to September was 2.0 kg/d and from September to November it increased to 2.5 kg/d for both the VEW and EW treatments.

From November to January VEW and EW heifers had significantly (P<0.05) greater gain (0.82±0.03 kg/d and 0.84±0.03 kg/d) than NW heifers (0.71±0.03 kg/d). From November through to the end of May there were no significant (P>0.05) differences in gain among weaning treatments. Overall evaluation of ADG from birth through to the end of May showed that there were no differences (P>0.05) between EW and NW treatments, however VEW gained significantly (P<0.05) less (0.73±0.03 kg/d for VEW vs. 0.78±0.03 kg /d for EW and NW) over the course of that time period (Table 3.4). Heifers during the backgrounding period (Nov.-March) were fed a low energy ration to maintain a 0.75 kg/d rate of gain. There were no differences in morbidity or mortality rates among treatments for the pre-weaning and backgrounding periods. Figure 3.11 shows the growth in BW for heifers pooled over the three year period.

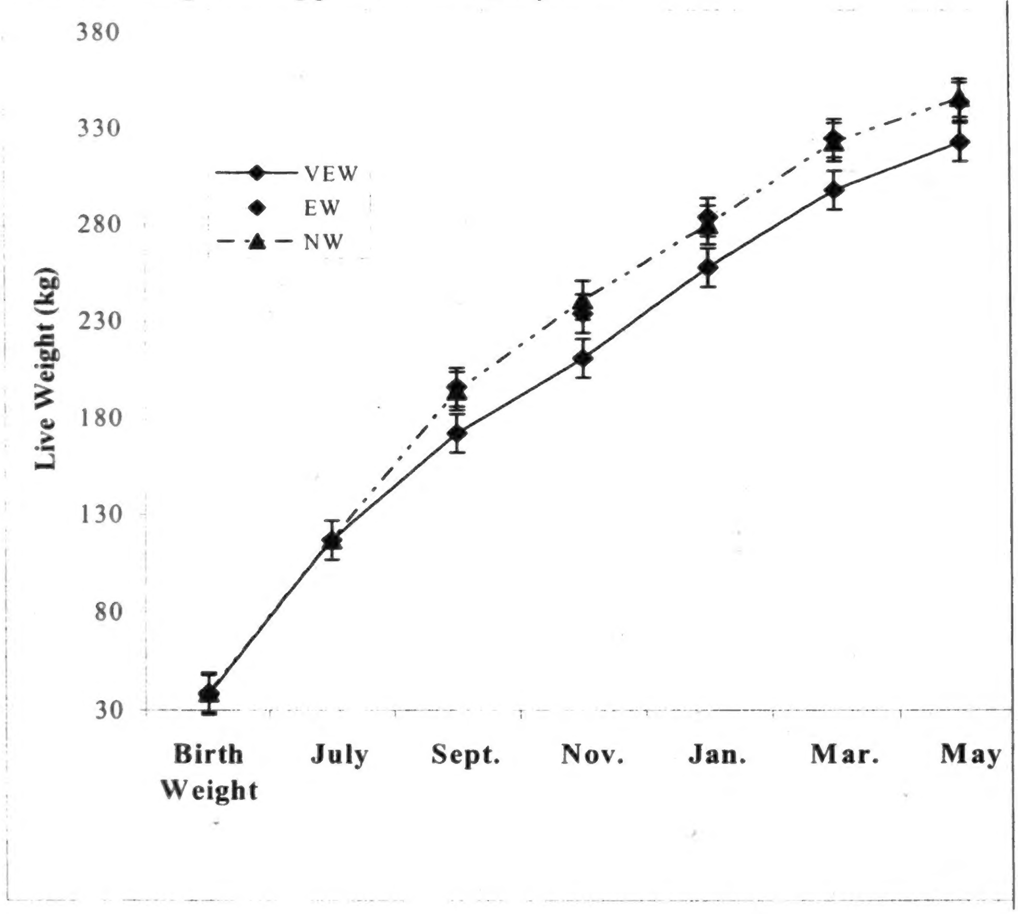
Table 3.4 The effects of VEW, EW and NW treatments on the growth rates of beef heifers over three years.[1]

Item	Treatment			
	VEW	EW	NW	SEM
No.	127	110	45	
Heifer weight, kg				
Birth	37	38	38	1.5
July	116	117	115	2.4
September	171[a]	195[b]	192[b]	3.0
November	208[a]	231[b]	235[b]	4.1
January	254[a]	278[b]	275[b]	4.8
March	295[a]	323[b]	321[b]	4.0
May	320[a]	343[b]	341[b]	3.8
Heifer ADG, kg/d				
Birth – July	1.10	1.11	1.12	.03
July- September	.90[a]	1.27[b]	1.25[b]	.03
September – November	.64[a]	.63[a]	.73[b]	.03
November – January	.82[b]	.84[b]	.71[a]	.03
January – March	.73[a]	.78[b]	.79[b]	.03
March – May	.34	.28	.30	.03
November – May	.65	.66	.67	.03
Overall: Birth – May	.73[a]	.78[b]	.78[b]	.03

[1] VEW = Very Early Weaned heifers; EW = Early Weaned heifers; NW = Normal Weaned heifers

[a,b] Means within a row with different superscripts differ (P<0.05).

Figure 3.11 Growth patterns in BW of VEW, EW and NW heifers from birth to the end of the backgrounding period over three years.*



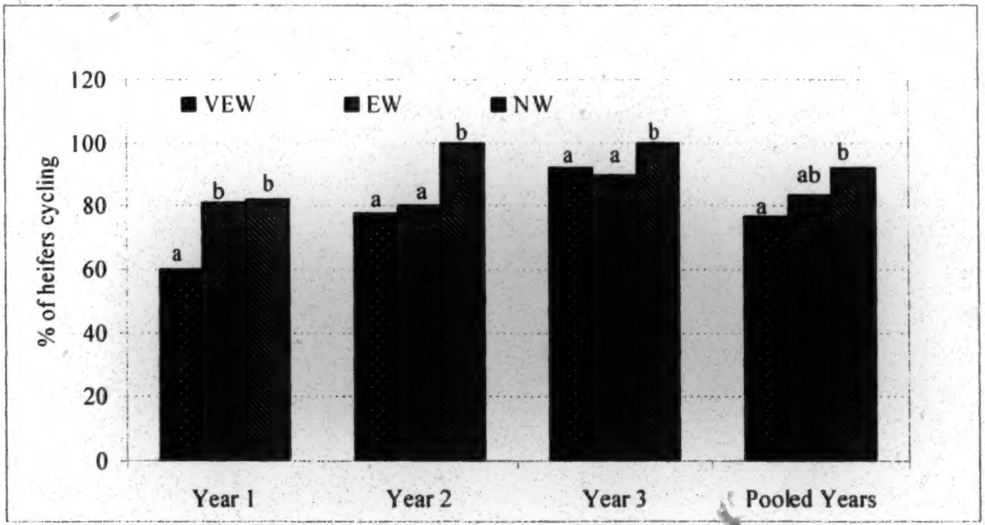
*VEW = Very Early Weaned heifers; EW = Early Weaned heifers; NW = Normal Weaned heifers

3.3.5 Heifer sexual development

Weaning treatment had significant effects ($P<0.05$) on the cyclicity of heifers the year after being backgrounded in the feedlot over the winter months. Results from the pooled data, showed that on average only 75% of the VEW heifers had cycled by the end of May compared to 84% for the EW and 94% for the NW heifers (Fig. 3.12). Year had a significant ($P<0.05$) effect on cyclicity by the end of May. In the first year results were

60%, 82% and 84%, second year 76%, 80% and 100% and third year 92%, 90% and 100% respectively, for the VEW, EW and NW treatments.

Figure 3.12 The effects of VEW, EW and NW treatments on the cyclicity in backgrounded beef heifers over the three years.[1]



[1] VEW = Very Early Weaned heifers; EW = Early Weaned heifers; NW = Normal Weaned heifers
[a,b] Means within a year with different letters differ ($P<0.05$).

3.3.6 Steer pasture/feedlot growth rates

Analysis of the data (Table 3.5) indicated that year had an effect ($P<0.05$) on steer growth rates, however, there was no carryover effect from one year to the next (because the steers were slaughtered at the end of each experimental year) and so the data were pooled. Weaning treatment had no significant ($P>0.05$) effect on birth weight and the July weights for the steers (Table 3.5 and Figure 3.13). From July to September unweaned steers gained 1.4 ± 0.04 kg/d, while very early weaned pasture (VEWP) and very early weaned feedlot (VEWF) steers gained 0.9 ± 0.04 and 1.1 ± 0.04 kg/d respectively. From September to November VEWP and VEWF rate of gain stayed constant, while early weaned pasture (EWP) and early weaned feedlot (EWF) gain dropped to 0.8±0.04 and 0.9±0.04 kg/d respectively; the normally weaned (NW) treatment steers' gain dropped to 1.0 ± 0.04 kg/d. Evaluation of the body weights after the last weaning treatment (Nov.), showed that VEWP differed from all treatments ($P<0.05$) and had the lowest weights at 223 ± 4 kg; VEWF and EWP were similar at 250 and 240 ± 4 kg respectively; EWF and NW were the heaviest ($P<0.05$) and weighed 265 and 270 ± 4 kg respectively. Average daily gain from birth to November (Table 3.6) was lowest ($P<0.05$) for the VEWP, similar and intermediate for VEWF and EWP, and similar and greatest for EWF and NW.

Average creep feed intake for VEWP steers from July to September was 2.0 kg/d, and from September to November it increased to 2.5 kg/d for both the VEWP and EWP treatments. Intakes of creep feed for the VEWF was 2.5 kg/d from July to September and 3.0 kg/d from September to November for VEWF and EWF, respectively.

3.3.7 Steer finishing performance

There were no differences ($P>0.05$) among weaning treatments for overall feedlot average daily gain (Jan. - Slaughter) (2.0±0.10 kg/d), however, during the warm up period to full feed from November to January NW steers gained less than the VEWP, VEWF, EWP and EWF steers (Table 3.6). From January to February NW steers had a significantly ($P<0.05$) greater ADG (2.2±0.07 kg/d) than the other treatments and compensated for their lower performance during the previous time period. Birth to slaughter ADG was similar for all treatments. Days on feed did not differ ($P>0.05$) among treatments. Slaughter live weight differed across treatments; VEWP (538 ± 7 kg) had the lowest followed by VEWF and EWP (556 and 562 ± 7 kg) and the heaviest live weights being for EWF and NW (577 and 577 ± 7 kg). The feed : gain ratio was lowest (most efficient) for EWP and NW, followed by VEWF and EWF with VEWP having the greatest feed to gain ratio. There were no differences in sickness or morbidity among treatments for the pre-finishing and finishing period.

Table 3.5 The effects of VEW, EW and NW treatments on steer BW and growth rates pre finishing over three years.[1]

	Treatment					
Item	VEWP	VEWF	EWP	EWF	NW	SEM
Number	66	59	65	57	60	
Steer weight, kg						
Birth	42	42	42	43	42	0.9
July	122	126	118	124	124	2.8
September	178^{a}	194^{b}	195^{b}	204^{c}	208^{c}	3.5
November	223^{a}	250^{b}	240^{b}	265^{c}	270^{c}	4.4
Steer ADG, kg/d						
Birth - July	1.1	1.2	1.1	1.2	1.2	.03
July- Sept.	0.9^{a}	1.1^{b}	1.3^{c}	1.4^{c}	1.4^{c}	.04
Sept. – Nov.	0.8^{a}	1.0^{b}	0.8^{a}	1.0^{b}	1.0^{b}	.04
July – Nov.	0.8^{a}	1.0^{b}	1.0^{b}	1.2^{c}	1.2^{c}	.06
Birth – Nov.	0.9^{a}	1.1^{b}	1.1^{b}	1.2^{c}	1.2^{c}	.07

[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normally Weaned steers

[a,b,c] Means within a row with different letters differ ($P<0.05$).

3.3.8 Steer slaughter and carcass traits

Slaughter age did not differ ($P>0.05$) among treatments (Table 3.6). Hot carcass weights were the lightest ($P>0.05$) for the VEWP and VEWF, intermediate for EWP and heaviest for EWF and NW treatments. VEWP and VEWF steers had significantly ($P<0.05$) less external fat than EWP, EWF and NW treatments. Rib eye area at the 12 and13 rib interface was the least for VEWP, intermediate for VEWF, EWP and NW and greatest for EWF ($P<0.05$). When REA was expressed as a proportion of hot carcass weight there were no significant ($P>0.05$) differences among treatments. Carcasses were visually appraised for marbling and graded according to the guidelines of the Canadian

Food Inspection Agency (CFIA); the results are presented in Table 3.6. No statistical analyses of marbling scores were done. Percentage carcass yield (hot carcass weight as a percentage of slaughter weight) tended ($P<0.10$) to be lower for VEWF than the other treatments.

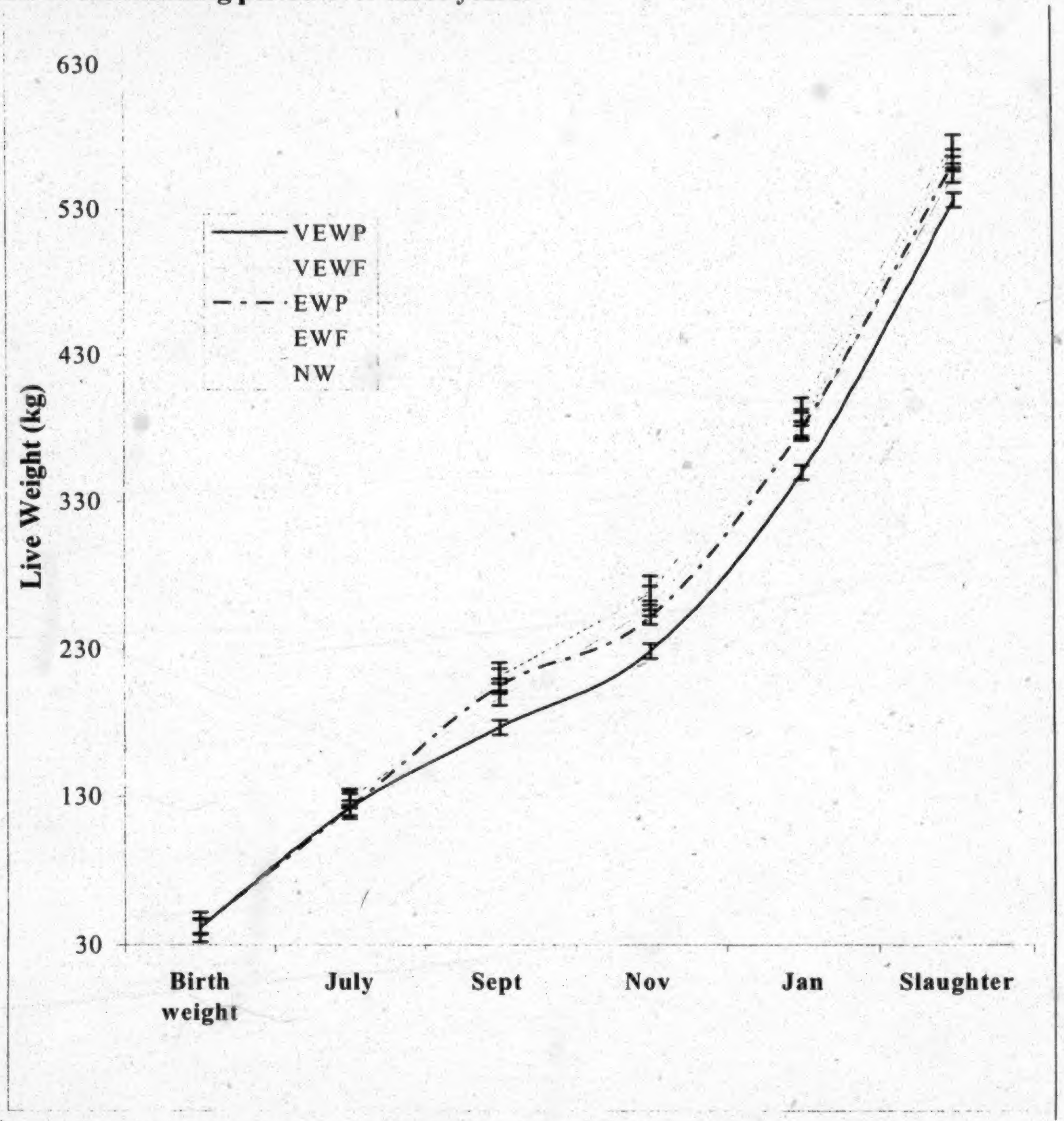
Table 3.6 The effects of VEW, EW and NW treatments on steer finishing performance and carcass characteristics over three years[1]

Item	Treatment					
	VEWP	VEWF	EWP	EWF	NW	SEM
Number	66	59	65	57	60	
Feedlot performance						
Initial weight, kg	223^{a}	250^{b}	240^{b}	265^{c}	270^{c}	4.5
Second Implanting weight, kg	393^{a}	420^{b}	449^{b}	475^{b}	446^{b}	6.6
Slaughter weight, kg	538^{a}	556^{ab}	562^{b}	577^{b}	577^{b}	6.8
Days on feed	178	175	177	175	176	1.5
Steer ADG, kg/d						
November – January	1.3^{c}	1.1^{ab}	1.2^{bc}	1.2^{bc}	1.0^{a}	.07
January – February	1.8^{a}	1.9^{a}	1.9^{a}	1.9^{a}	2.2^{b}	.08
February – March	1.5^{b}	1.3^{a}	1.3^{a}	1.3^{a}	1.4^{a}	.07
March – April	1.7	1.7	1.8	1.7	1.8	.09
January – Slaughter	2.0	2.0	2.0	1.9	2.1	.10
Birth - Slaughter	1.3	1.3	1.4	1.4	1.4	.07
Feed: Gain	6.7^{c}	6.3^{b}	6.0^{a}	6.4^{b}	6.1^{a}	.07
Carcass characteristics						
Slaughter age, d	380	384	382	382	382	2.1
Hot carcass weight, kg	298^{a}	307^{a}	316^{ab}	322^{b}	323^{b}	4.5
External fat thickness, mm	12.0^{a}	12.3^{a}	14.1^{b}	14.0^{b}	14.3^{b}	0.6
REA cm^2	77.2^{a}	80.2^{ab}	81.5^{ab}	83.2^{b}	80.2^{ab}	1.1
REA cm^2 / kg carcass	.26	.26	.26	.26	.25	.01
Quality grade	2.3	2.3	2.3	2.4	2.3	.08
AAAA %	0	0	2	0	4	
AAA %	27	35	32	36	33	
AA %	69	56	64	64	58	
A %	4	9	2	0	5	
% Carcass Yield	56.1	55.4	56.4	56.2	56.0	0.4

[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normally Weaned steers

^{a,b,c,d}Means within a row with different letters differ ($P<0.05$).

Figure 3.13 Growth patterns in BW of VEW, EW and NW steers from birth to the end of the finishing period over three years.[1]



[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normal Weaned steers

3.4 Discussion

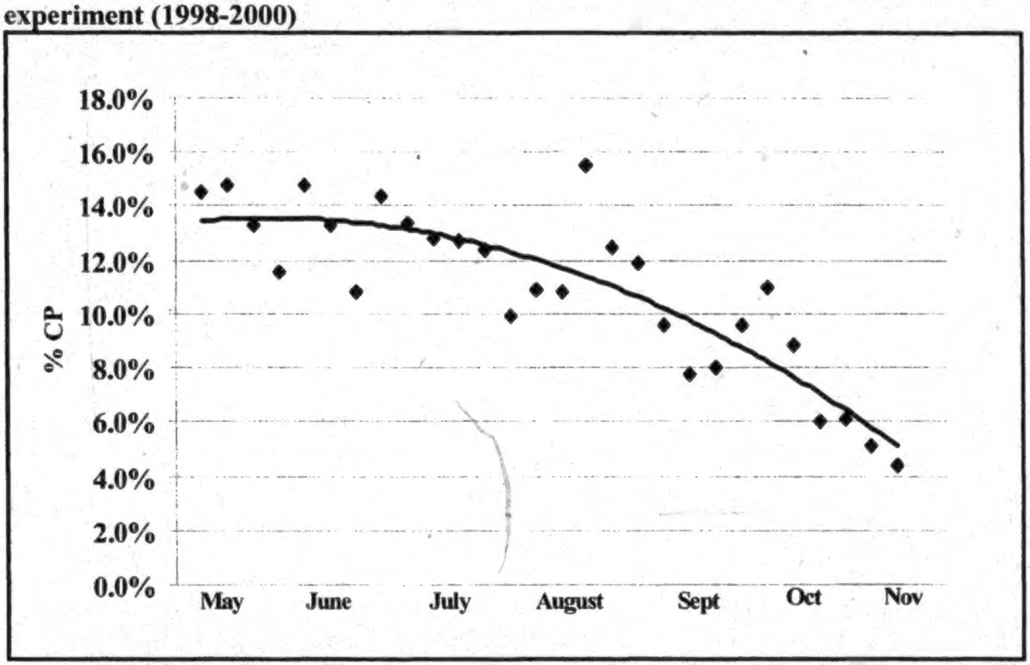
3.4.1 Cows

This study shows that repeated very early weaning (VEW) and early weaning (EW) of spring calving cows over a three year period results in cows that have greater BW and BCS than cows that were weaned (NW) at 192 d. Body weight and BCS changes were cyclical in nature and all treatments lost and gained BW and BCS over the course of each year. The amplitude of the loss or gain in BW and BCS can partially be explained by differences in the energy requirements between lactating and nonlactating cows. Cows producing 10 kg of milk /day require 20% more energy and 35% more crude protein than otherwise similar non-lactating cows (NRC, 1996). So if the nutritional value of the pasture is beyond the requirements of the cow, she can put more towards body fat deposition. These findings are similar to those of Myers et al. (1999a) and Story et al. (2000) who showed that weight and condition score changes were cyclical and more dramatic, the later cows were weaned.

Only in one year (2000) out of the three in the present study did the NW cows recover some of the BW lost from September through to November prior to the winter feeding period. As expected the VEW cows had the greatest increase in BW and BCS followed by the EW cows and then the NW cows, which had the least change in BW and BCS over the course of this three-year study. The differences in BW and BCS can, in large part, be explained by reductions in the nutrient requirements for lactation (NRC, 1996); VEW cows could partition consumed nutrients towards weight gain and increased body condition beginning in July, EW in September but NW cows not until November. However, by November forage quality and quantity was dramatically lower, therefore reducing the opportunities for the NW cows to make up for lost BW and BC. Peterson et al. (1987) indicated that cows with EW calves consumed 45.3% less total digestible nutrients from hay than cows with NW calves and that EW cow/calf pairs were 43.0% more efficient in converting TDN into calf gain than were normally weaned cow/calf pairs. Although VEW cows had the greatest gains in BCS from July to September, the magnitude of the BW increase was not as great as would be expected. The smaller than expected BW increase may be explained by several factors. First, forage quality and quantity were not limited from July through to September (Figure 3.14 and Figure 3.15). Pastures at the time of VEW had feed values in excess of 12% CP and 60% TDN. These feed values were greater than would be needed to maintain lactation and so excess nutrients could be partitioned to BW and BC gain. Forage quality changes were monitored using fistulated steers. Grings et al. (1995) concluded that there were minimal differences in forage quality selection between cows, calves and mature steers.

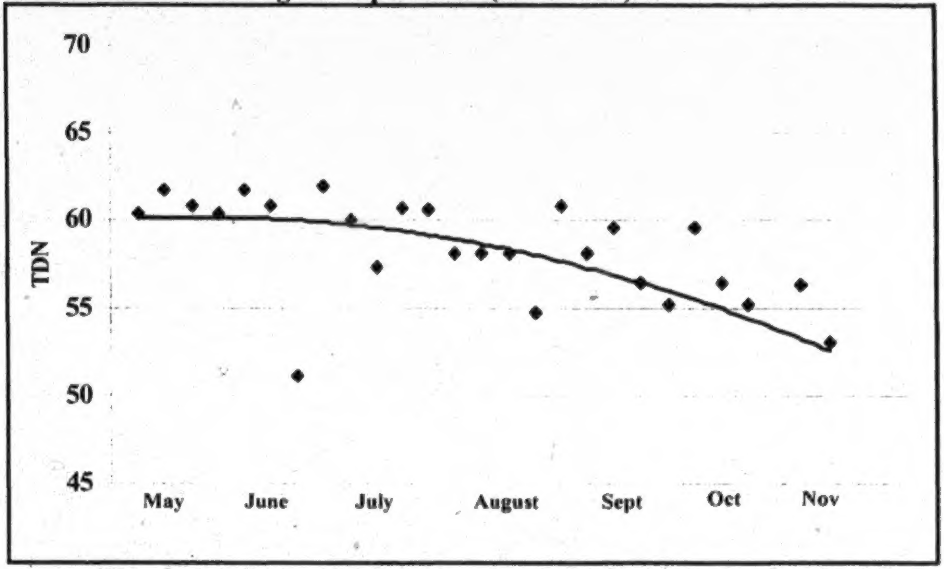
Secondly, cows from all treatments across the three years had lost BW from calving prior to the first weaning period; the gain in BW from July through September that occurred across all the treatments may have also been a result of compensatory gain. Boadi and Price (1996) found similar results in post partum compensatory gain in cows that were nutritionally restricted or had lost BW pre calving. The final factor that may have influenced BW gain over the three year study may simply have been animal growth. The average age of cows at the start of the experiment was 6 ±0.02 years. Cows, if previously nutritionally deprived, may continue to grow past the age of seven (Wilson and Osbourn 1960). This may explain the increase in BW with only a slight increase in BCS. Should the forage quality and quantity have become limited the magnitude of the differences in BW and BCS among treatments could have been even greater. These results agree with other research showing that cow body condition score increased as calf weaning age decreased (Myers et al. 1999b). In addition, Neville and McCormick (1981) and Grimes and Turner (1991) reported that cows whose calves were weaned early were heavier in weight and had greater body condition scores than cows whose calves were weaned 110 or 163 d later. This study supports the hypothesis that earlier weaning of cows directly increases cow BW and BCS.

Figure 3.14 Changes in CP content of pastures grazed by fistulated steers during the experiment (1998-2000)



*Note feed quality sampling was done using mature fistulated steers. Data by Grings et al. (1995) validated that using fistulated steers was an accurate method of assessing forage quality changes through the grazing season.

Figure 3.15 Changes in Total Digestible Nutrients (TDN) in pastures grazed by fistulated steers during the experiment (1998-2000)



*Note feed quality sampling was done using mature fistulated steers. Data by Grings et al. (1995) validated that using fistulated steers was an accurate method of assessing forage quality changes through the grazing season.

Although year had an effect on calf birth weights they were not affected by weaning treatment. The difference from one year to the next would largely be accounted for by cow age. It is well established that cow size is the most important determinant of birth weight; the heavier the cow the heavier the birth weight (Franke et al. 2001). Cows at the end of this three year study weighed more than at the start of the study, likewise calf birth weights were heavier at the end of the study than at the beginning. The change in birth weights over the three year period may simply have been a reflection of the maternal influence (ratio of birth weight to dam weight). Other factors influencing birth weight would include feed restriction during the last trimester prior to the start of the experiment (Boadi 1993; Weder 1999) and different combinations of sires used on the cows.

Prepartum body condition score is one of the most important factors determining reproductive performance of beef cattle (Richards et al. 1986). Many authors have concluded that a minimum body condition score of 2.5 on a five point scale (Lowman et al. 1973) is needed at calving to ensure a 70% conception rate within each 21 d breeding cycle (Whitman 1975; Deziuk and Bellows 1983). Cows in this experiment were exposed for a 42 d breeding period, so with an expected conception rate of 70% / 21 d cycle, pregnancy rates should have been 91% after 2 cycles. In the first year of the experiment conception rates for the VEW and EW cows mirrored the expected outcome, with 93.8 and 91.6% pregnancy, however the NW treatment had a lower conception rate (85.4%). There are no explainable reasons for the lower pregnancy rates in NW.

In the second year, conception rates for the VEW and EW treatments were slightly lower than Year 1 and the NW treatment improved; these results may reflect the culling policy resulting in animals that were more fertile. In the third year, conception rates for all treatments were slightly reduced (VEW: 88.8% vs. 90.6%; EW: 84.1% vs. 85.7%; NW: 90% vs. 94.1%) when compared with the previous year; there were no differences among the treatments.

With two exceptions, the cows in these treatments did not fall below the 2.5 BCS threshold (Whitman 1975; Deziuk and Bellows 1983), and so over a three-year period, weaning had no significant influence on pregnancy rates or calving interval. In studies in which this was not inherent in the experimental design, early weaning improved cow body condition at calving and subsequent reproductive performance by reducing the postpartum interval and improving conception rate (Laster et al. 1973; Bellows et al. 1974; Myers et al. 1999b).

Very early weaning (prebreeding) will reduce the lactational stress, while early weaning may simply improve the BCS for the next calving season, which would improve conception rates and reduce the subsequent calving interval (Barnes et al. 1996). Lactation in the cow is associated with high levels of prolactin (Webb and Lamming, 1981) and the increased prolactin concentrations are strictly correlated with the presence of the suckling stimulus. Calf removal will result in a rapid decline in plasma prolactin levels and increase the basal LH secretions. This may explain the marginal improvement in conception rates for the VEW treatment, even though there were no statistical differences ($P>0.05$) in pregnancy rates in this experiment.

Cow culling rate was the lowest for EW cows followed by VEW and highest for the NW cows at the end of the three-year period; (33.2%, 42.3% and 46% respectively - Table 3.3). In the first year the NW cows had lower conception rates (all open cows were culled) and from the first to the second year a number of cows were culled from the EW treatment due to abortions, death losses and feet and udder problems. These reductions in animal numbers early in the trial largely explained the difference in retention by the third year. These results disagree with those of Story et al. (2000) who concluded that there were no differences in retention rates for early, normal and late weaned mature cows. In their study EW cows were weaned at 150 days and there was no very early weaned treatment.

3.4.2 Heifers

Although the VEW heifers had access to creep feed and good quality pasture from July through September, gains were significantly lower ($P<0.05$; 0.9 vs. 1.3 and 1.3 kg/d) than the EW and NW treatments. The VEW heifers at weaning were on average 70±12 d of age. Tamate et al. (1962) and Church (1975) have shown that nursing beef calves only become functioning ruminants at about 80-90 d. Thus, these calves, although not naïve to grazing, probably did not have enough foraging experience nor were their digestive systems fully developed and so this may explain the poorer performance. Other researchers (Richardson et al. 1978; Lusby et al. 1981; Basarab et al. 1986) have documented similar results in which very young early-weaned heifers gained less than heifers weaned at a later date. However, this is in contradiction to research conducted by Makarechian et al. (1988), in which early weaning of heifer calves had no effect on subsequent ADG or BW compared to that of heifers weaned at 200 days; EW calves in this trial were on average 150 d of age at weaning. Nutrient requirements for beef heifers weighing less than 180 kg are not well documented in the literature. Therefore, it is plausible that the combination of pasture with creep feed fed to the 70d – old weaned calves was not balanced appropriately to support a similar average daily gain (1.25 kg/d) to those of the unweaned calves. The weight gain may have been supported to a greater degree from a lactating cow in regards to energy, degradable and undegradable protein, vitamins, and minerals (NRC, 1996). From September to November VEW heifers had greater ADG than the EW heifers. The improved performance may be related to the calves being older (mean age 132±12 d), the rumen being more developed, reduced naiveté towards feed and water sources, and compensatory gain from the previous time period after the initial post weaning period (Yambayamba and Price 1997). Explanations for the depressed gains of the EW treatment may be related to poorer pasture quality by September (Figure 3.14 and Figure 3.15) and no access to creep feed pre-weaning compared with the VEW treatment. Grings and coworkers (1995) established that diet quality selection in calves is more selective early in the growing season than in steers and cows were less selective than steers. However as the grazing season progressed differences between the animal classes became negligible. The fistulated steers would be a good indicator of feed quality selected and give a good indication of forage quality changes throughout the grazing season.

Stress associated with weaning and separation from the dam may also have been factors (Fluharty et al. 1997). Both EW and NW treatments had reduced gains from September through to November, while VEW calves had improved gains compared to the previous time period. In beef cows, milk production peaks at 70-90 d postpartum; and forage quality in terms of CP and TDN declined from September through to November (Fig 3.14, 3.15) which is a likely explanation for the decreased BW and BCS in the cows and decreased gains in their calves (Pordomingo 2002).

The nutrient content of the milk, especially the degradable and undegradable protein characteristics, is an important component that may need to be taken into account when early weaning calves. Jenkins-Hollingsworth et al. (1995) indicated that it is the quality, not the quantity of the milk during late lactation in beef cows that allows for the calf to gain weight while still grazing poorer quality pastures that are decreasing in nutrient quality. More recent work by Reynolds and Tyrrell (2000) confirmed that in the later stages of lactation (28-32 weeks) milk volume and fat content decreased, while milk protein levels increased. This may explain why NW calves still had better gains from September to November even though forage quality was declining.

From November to January the VEW and EW heifers continued to increase their rate of gain, while NW gains were reduced. Previous researchers have documented similar findings (Fluharty et al. 1997; Myers et al. 1999a). The reduced ADG in those experiments were related to late weaning and increased levels of morbidity brought on by weather coupled with nutritional and weaning stress. There were no differences in morbidity and/or mortality found in this study, however weaning stressors like the breaking of the filial/maternal bond and the naiveté of the heifer calves to new feeds may have all been contributors to the reduced gain immediately post weaning.

From January through to March, NW heifers improved in performance and gained marginally better than VEW and EW heifers. This gain more than likely related to compensatory gain from the previous time period. Boadi and Price (1996) found similar post weaning catch-up or compensatory gain in heifers that were nutritionally restricted pre-weaning. In this experiment, the performance of VEW and EW heifers improved as they became older, indicating that the ration was better meeting their nutrient needs for ADG. Although gain increased for all treatments, overall ADG still indicated that VEW heifers gained less than EW and NW. Explanations for the reduced gains would be related to the depressed gains immediately post weaning (July to September), the restricted energy content of the heifer backgrounding ration and insufficient time for the VEW to fully compensate for the weight difference. Boadi and Price (1996) found similar results in that compensatory gain was directly related to the energy level of the ration. In their study early weaned steers that were on an unrestricted finishing diet had similar live weights to normal weaned steers calves by spring, whereas early weaned heifer calves that were on a restricted backgrounding ration did not have similar live weights to normal weaned heifers until 24 months of age.

As would be expected the number of heifers cycling at the end of May was closely related to their live weights. Pooled results for the three years indicated that 75% of VEW, 84% of EW, and 94% of NW heifers were cycling by the end of May. Gordan (1993) indicated that first estrus is chiefly a function of body or target weight (65-70% of its mature weight pre breeding), but will vary with breed (British breeds mature at lower weights than Continental breeds), plane of nutrition and season of birth (photoperiod influences). By the end of May, VEW heifers had not recovered from the decreased post-weaning growth (Figure 3.11); they were still 21 – 25 kg lighter than EW and NW heifers, and this may explain the reduced cyclicity. Year also had a strong influence on the cyclicity of all the weaning treatments. In the first year heifers in all treatments had lower live body weights than in second and third years and it showed in a corresponding decrease in cyclicity across all treatments. Similarly in year two, live weights at the end of May were greater for all treatments, which resulted in more heifers cycling. Explanations for the differences in cyclicity between the EW and NW treatment may also have been related between the pre and post weaning daily gains. Weight at first estrus indicated that NW heifers had been gaining faster and therefore tended to be heavier by the end of May. Similarly, Arije and Wiltbank (1971) observed that heifers that grew faster pre-weaning tended to reach puberty at an earlier age and at a heavier weight, while heifers that grew rapidly from weaning to puberty tended to be heavier but were not necessarily younger at puberty. Boadi and Price (1996) found reduced cyclicity in heifers that were early weaned. They attributed the differences in cyclicity to a backgroound ration that restricted live weight gains of the early weaned heifers and did not allow them to fully compensate their weight, similar to this study.

3.4.3 Steers

There was no significant effect (P>0.05) of weaning treatment on the birth weight or growth rates of steers to July; these results are parallel to those documented from the heifers in this study. From July to September both VEWP and VEWF had lower gains than the unweaned treatments. The lower gains presumably resulted from a change in nutritional status that was inadequate to match the gains of the unweaned calves. VEWF steers gained better than VEWP steers and continued to do so until November; differences between treatments were due to the nutrient content of the diet. The VEWF steers were fed a complete ration, whereas the VEWP consumed pasture that was decreasing in crude protein and energy content over the duration of the grazing period (Figure 3.14 and Figure 3.15). Similarly EWF steers gained faster than EWP. Although the gains for the first two months post weaning were better for the EWP and EWF than they were for the VEWP and VEWF, they reflected the same trend as in the VEWF and VEWP treatments immediately post-weaning. Gains from September to November in the NW steers parallel those of the heifers reflecting a decrease in forage quality and quantity, reduced cow milk production and an increase in competition for increasingly limited grazing resources by the cow and calf. Gains for EWP steers were 20% reduced as compared to NW steers. These pre weaning results agree with previous research (Lusby et al. 1981; Lusby and Wettemann 1986; Lusby et al. 1990) in which immediate post weaning results were reduced over unweaned animals.

The feedlot phase allowed for a realimentation from nutritional restrictions imposed earlier during the weaning and pre-weaning period, and an opportunity for catch-up growth (Yambayamba and Price 1997). Results indicate that the ability of the steers to recover and attain comparable slaughter weights was not significantly (P>0.05) influenced by weaning age.

During the finishing stage there were still several points at which weaning treatments significantly (P<0.05) affected steer feedlot performance. From November to January during the start of the finishing period, NW steers had reduced gains compared to VEW and EW steers. The lower gains could result from the residual effect of weaning stress brought on by a combination of nutritional, weaning and weather related factors. Myers et al. (1999a) found that early weaned and normal weaned calves with creep feed had less respiratory and digestive morbidity than normal weaned spring born calves. Even though live weight gain decreased immediately post weaning for the NW steers, by February they had compensated in gain and made up for the poorer performance of the previous month, supporting the weaning stress argument. By slaughter, differences in live weight among weaning treatments were decreasing yet the VEWP steers were still significantly lighter (P<0.05) than all other groups except the VEWF steers, which were intermediate (Table 3.6).

Examination of the carcass characteristics revealed that VEWP and VEWF steers had less back fat cover, smaller rib-eye areas (REA), and lighter carcass weights than the other treatments. However when REA was expressed as a proportion of REA/ carcass weight, VEWP and VEWF steers were similar to the other weaning treatments. If the VEWP and VEWF steers had remained on feed for an additional two weeks the differences in live weight and carcass quality may have disappeared. Due to the distance to the packing plant and the need to gather carcass data, cattle were shipped when the majority of pen was deemed to be finished so that trucks were full. This however resulted in some cattle being slaughtered before they should have been; a ranch management plan that did not allow the opportunity to examine the length of time it took for VEW steers to reach the same target weight as the other treatments.

The reduced back fat cover in the VEW steers is in contradiction to information reported by Story et al. (2000), who found higher backfat cover on very early weaned calves. We used a more aggressive implant program in this study and the growing period of the background stage may explain the differences. The differences in body fat depth and subsequent carcass quality may partially be explained by a study from Myers et al. (1999b) which compared the visceral and digestive tract weights of early-weaned steers receiving a high concentrate diet with those grown on pasture before finishing. They found that pasture backgrounded steers tended (P=0.15) to have a 12% larger liver weight and 14% larger (P=0.01) rumen weight than steers fed on a high concentrate diet. Myers et al. (1999b) concluded that these organs have higher energy requirements per unit of mass than the body average and would have had greater energy expenditures per unit of weight reducing the energy that could be partitioned to fat deposition and growth. Examination of the feed to gain ratio (Table 3.6) showed that VEWP steers converted the least efficiently (P<0.05) and had the lowest carcass weights, supporting the conclusion of Myers et al. (1999b).

The effect of weaning age on quality grade in other research has led to the conclusion that more early-weaned steers than normally weaned steers graded AAA or greater (Fluharty et al. 1997; Meyers et al. 1999a; Meyer et al. 2005). Conversely, some research (Schoonmaker et al. 1998) has shown no effect of age at weaning on carcass fat depth, quality grade, hot carcass weight, or percentage grading USDA Choice or higher.

Carcass characteristics can be affected by a number of factors including days on feed, genetics, age, gender and implant strategies. In the present experiment, all treatments had the same number of days on feed, and were implanted twice, which has been shown to decrease the marbling and quality grades of cattle (Kuhl 1997). Carcass characteristics, feed: gain ratios and ADG were not significantly (P>0.05) different among the EWP, EWF and NW treatments.

The feedlot phase allowed for a longer period to recover from the imposed earlier weaning on the steers. Overall, it was found that VEWP, VEWF, EWP and EWF steers had the ability to recover from their early weaning setback and attain comparable slaughter weights to those of NW calves. Very early weaned steers, backgrounded on pasture may need a longer period to recover.

3.5 Implications

The information gained from this experiment has far reaching ramifications for the western Canadian beef industry. First and foremost it has demonstrated that very early weaning (<90 days) can be done successfully with no greater incidences of morbidity or mortality than later weaning. Very early weaning in this experiment did not shorten the post partum breeding interval nor did it improve the conception rates compared to the later weaned treatments. This indicates that there was neither a nutritional short fall nor any BCS limitation of the cows that would have warranted weaning a calf at such a young age. The only way very early weaning may be justified, would be in the case of culling cows early to take advantage of seasonal price changes for cull cows or during severe drought, where young cows in poor body condition could have jeopardized conception rates. If calves are weaned under these situations a high level of nutritional management would be required, if the desire is to keep gains similar to those of calves that are still nursing. These types of gains would be best achieved in a feedlot feeding program. More research into the nutritional requirements of very young beef calves (<70 d age) would also be warranted.

During more normal years delaying weaning by another 60 to 130 d, would result in calves that gain as well as normally weaned calves but require less strict nutritional management compared to very early weaning. In comparing early weaning (132 d) to normal weaning (193 d) there was little to no significant difference in growth rates, carcass qualities or finishing weights among steer treatments. This suggested that early weaned (>130 d) calves had a digestive system that was mature enough so that the calf could grow independently of the dam. For the heifers the only difference was that very early and early weaned heifers had lower cyclicity at the end of May than normally weaned heifers.

Although there were no major differences in body weight gain between early and normally weaned calves there were differences in cow body weight and body condition for the two treatments. Early weaned cows maintained weight and increased in body condition during the 60 days post weaning (Sept. - Nov.) whereas normally weaned cows lost weight and body condition during the same time period. What was interesting in this experiment was that there were no perceived limitations in forage availability for fall grazing. The normally weaned cows eventually gained back the weight lost during the winter feeding period (Jan.- April) indicating that the cows compensated for the previous weight loss and were fed above their needs for maintenance.

The main shortfall in this experiment was that the limit of the cows reproductive and body condition flexibility was not tested. This experiment showed that cow body condition and body weight could be manipulated by weaning but it did not show the impact it could have on reducing winter feed costs. Winter feed expenses have been identified by many (Lusby et al. 1981; Story et al. 2000) as the greatest cost in cow/calf production. It was unfortunate that the winter feeding component in this experiment had to be abandoned. Future research should investigate the limits of body condition score management. Weaned treatments (cows) should be feedlot fed so that variables that exist on open pasture winter feeding could be eliminated. Then the winter feeding program should be designed to harvest the body condition and see how much could be saved on winter feeding rather than allowing cows to have compensatory gain as they did in this experiment. Other areas of potential research in relation to this experiment would be the comparison of different cow biological types. Having a comparison between different body sizes and milk production potential would be valuable information for cow/calf producers.

In conclusion even though weaning has a strong influence on the growth rates of both cows and calves, the factors of feed, yardage and management will have to be evaluated. Weaning is a tool, understanding how it can beneficially affect one enterprise and yet add costs to another is key if weaning is to be seen as a way of reducing costs of production. The next chapter will discuss those factors and how they can be evaluated and measured in an economic framework.

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CHAPTER 4

TIME OF WEANING: THE ECONOMIC IMPLICATIONS AND DECISION MAKING TOOLS

4.1 Introduction

Economic pressures to improve production efficiencies in the beef industry have prompted many researchers to evaluate various production systems (Peterson et al. 1987; Adams et al. 1994; Faulkner et al. 1994). These researchers realize that the profitability of the beef cattle industry will depend in part on its ability to compete with other meat industries like pork and poultry. To compete effectively, the beef industry must continue to strive for low costs of production while providing a product that will meet the customer's demand for consistency, quality and safety.

Over 70% of the energy consumed by a cow goes to maintenance, while only 30% may go to fat deposition, growth and or milk production (Jenkins and Ferrell 1983). The beef industry has been able to compete with pork and poultry by utilizing pasture and forages for a large proportion of those energy needs. However, maintaining pasture productivity and calf gain during drought and even during normal cyclical changes in forage quality and quantity throughout the year can be difficult and as a consequence supplemental feed costs can account for half to three quarters of the annual cost of keeping a cow (Taylor 1984; Kaliel 2004). There are numerous management practices that can alter the amount of supplemental feed. These management practices may include changing the season of calving, altering the grazing system or simply changing the genetics in the herd. Another management procedure that may have an effect on the economics of cow/calf production efficiency is altering the time of weaning. Peterson et al. (1987) reported that early-weaned cow/calf pairs were 43% more efficient in converting total digestible nutrients into calf gain than were normal weaned cow/calf pairs. Weaning can manipulate cow body condition and average daily gain; thereby resulting in an increase in reproductive rates and reduction in cow winter-feed costs (Lusby et al. 1981; Richards et al. 1986). If forage quantity and quality become limited, the longer or shorter a cow nurses will correspond to a decrease or increase in body condition. Many researchers have found that early weaning, improves cow body condition, pregnancy rates, increases pasture carrying capacity and improves the overall profitability of the cow/calf enterprise (Myers et al. 1999a; Story et al. 2000; Pordomingo 2002). However, the benefits of early weaning that accrue to the cow have to be balanced with the costs incurred by the calf, especially if calves are sold at weaning. Weaned calf sales contribute a great percentage of gross income to a cow/calf operation. Thus, before changing the age of weaning, careful evaluation of the costs and benefits associated with an early weaning system will need to evaluated.

This chapter will discuss key production and economic variables that can be affected by weaning and what economic approaches can be used to measure them.

4.2 The economics of traditional weaning

In an audit done by Alberta Agriculture (1999); the average calving date in the province was the 1st of March and the average weaning date was the 28th of October. This made the average age at weaning 7 months. More recently, data from North Dakota State's Extension service indicated the average weaning age of calves at weaning was 192 days (Ringwall 2005). Why are calves weaned at seven months of age? Some researchers claim that it stems from the purebred industry (Lusby 1996). To make a fair comparison of animals born on different dates, the purebred industry adjusts all animal weaning weights to 205 days. The argument being that if weights were not adjusted to a constant age replacements and bulls would just be selected from the older animals. The practice of adjusting weights to a constant age may have led many in the commercial cattle industry to the notion that their calves should be weaned as near to 205 days of age as possible. In fact there is little basis for this practice to commercial producers and there are many other factors that should dictate weaning age besides an arbitrary number adopted primarily due to its repetition rather than relevance in commercial cow herds (Lusby 1996).

More appropriate reasons for weaning at 7 to 8 months of age include: 1) substantial decline in the lactation curve, which may reduce the energy need to maintain the cow 2) it allows sufficient time for a cow to prepare for her next calf, and 3) a cheap and abundant forage supply that costs less than the yardage and management needed to achieve similar gains through confined feeding for the calves.

4.3 Economics of cow body condition and herd productivity

The body condition of beef cows at calving is highly associated with length of the postpartum interval, pregnancy rates, lactation performance, health and vigour of the newborn calf, and in some cases, the incidence of calving problems (dystocia) (Lusby et al. 1981; Richards et al. 1986; Herds and Sprott, 1987).

Benchmarks and production efficiency parameters are often used as a method of identifying weaknesses that limit profit potential. Researchers working for Alberta Agriculture (1999) have identified such a set of parameters and these are referred to as the "GOLD" indicators. GOLD stands for; Growth, 45% weaning weight of dams mature weight by 205 days; Opens, less than 4% non pregnant among mature cows; Length of calving season, 63 days or less; Death loss, calf death loss less than 4%. In the 1999 Alberta Agriculture beef cow calf audit, the average weaning weight for calves was 38% of the mature cows weight, open rates were 3.8%, length of calving season was 95 days and calf death losses were under 3.5%. The profit opportunity from improvements in the 'GOLD' indicators was estimated at $63 per cow when $1.25 per lb was the assumed price for 550 lb weaned calves. Reducing the length of the calving season to 63 days, thereby better matching nutritional and management needs to the cow herd, had the best profit opportunity at $23 per cow in the breeding herd. In the 1999 audit, average conception within the first 21 days of the breeding season was less than 50%. To achieve a 96% pregnancy rate in a 63-day breeding season, average conception per 21-day cycle would need to be 70% of cows exposed (Alberta Agriculture 1999).

4.4 Economics of cow reproductive rates and cow depreciation

Whittier (1995) reported that cows classified as thin (BCS 1-2; scale 1 to 5 where 1 is emaciated and 5 grossly fat) at calving were 30% less likely to show estrus at 60 and 90 d post partum than cows classified as optimum (BCS 2.5-3; Table 4.1). Maintaining a 365-day calving interval requires a cow to rebreed within 85 days of calving. To optimize rebreeding, general management recommendations are for post partum cows to have at least one estrus cycle prior to the breeding season. If one third of cows have not had an estrus cycle within the 85 day postpartum period there would exist a major risk for low pregnancy rates if the breeding season is confined to a short time period.

Table 4.1 The effect of body condition score at calving on the % of cows reaching first estrus by 60 or 90 post partum. (Whittier, 1995)

	Days after calving to first estrus	
BCS at calving [a]	**60 d**	**90 d**
Thin (1.5-2)	46%	66%
Optimum (2.5-3)	61%	92%

[a] 1 to 5 scale; where 1 is emaciated and 5 grossly fat

Anestrous (absence of estrous or heat) is a condition that exists in most mammals after they give birth. It is contended that it is a self defense mechanism to allow the dam to recuperate after pregnancy (Short et al. 1990). Postpartum anestrous in cows is often a problem in younger and/or growing animals. The combined effects of suckling stimulus, behavioural responses and nutritional demands of milk production are all causes of post-partum anestrous (Short et al. 1990).

In the context of weaning as a management tool, suckling and lactation impact reproduction in two ways:

1) The short term effect of suckling lengthens the postpartum interval and may delay pregnancy during the breeding period in the year suckling occurs. This is especially true in young and thin cows.
2) The long-term effect of lactation may have an indirect effect on reproduction by reducing cow body condition score so that pregnancy is delayed or reduced in the year following the current lactation. This is especially true if a cow does not regain enough condition following lactation and her body condition slips on a continual basis. This is frequently seen in young cows that may breed adequately as two-year olds, but continue to lose condition as three-year-olds.

Oklahoma researchers (Lusby et al. 1981) have reported a 64% advantage (97% vs. 59%) in conception in first calf heifers that began calving in February when calves were weaned at six to eight weeks post partum, compared to heifers whose calves were weaned at seven months. Additionally, the average interval from calving to conception was reduced by 18 days (91 vs. 73 days). Body condition of the heifers in this study were not reported; however, the authors stated that their heifers were nutritionally stressed prior to calving, weighing five percent less after calving in the spring than they did the previous fall. Lusby et al. (1981) concluded that the positive response to weaning was because the heifers were in marginal condition at calving; heifers in good to moderate condition may have had a less dramatic response to changes in weaning dates.

Animal depreciation is an expense that must be factored into the cost of production. Depreciation as commonly defined is the declining worth of an asset (Pratt 2004). In the context of a beef cow, it is commonly defined as the difference in worth between a bred and open animal. Cow depreciation often does not get enough attention since winter-feed and feeding cost can be so significant to the cow/calf operation. However, with the reality of BSE in North America the salvage value of cattle over 30 months of age has been significantly reduced thereby increasing the expense of cow depreciation. Using cow depreciation in the context of the research from Lusby et al. (1981) the difference between a 96% and 56% conception rate is significant.

Assume:

100-cow herd that buys all bred replacements
Replacement value of bred heifer - $1350 / hd
Cull value of open cow - $800 / hd
Animal Depreciation - $550 / hd

converted costs on a per head basis:
Cost of animal depreciation 97% conception (3% replacement rate)- $16.50 / hd
Cost of animal depreciation 57% conception (43% replacement rate) - $ 236.50 / hd

Work conducted by Laster et al. (1973) showed that when calves were weaned eight days before the start of a 42-day breeding season, the percentage of cows exhibiting estrus from calving through breeding increased by 29% for first calvers, 27% for second calvers, and 16% for mature cows. Pregnancy rates were likewise increased by 26% in first calvers, 16% in second calvers and 28% in mature cows.

Whittier et al. (1995) studied the long-term effects of early (90 days) versus normal (205 days) weaning of first calf Angus sired heifers for three years. There were no statistical differences in pregnancy rates in any one year; however the normally weaned heifers had numerically lower pregnancy rates each year following the early weaning management treatment other than in the first year.

Dalsted and Gutierrez (1989) analyzed the number of years required for breakeven on replacement females at various replacement heifer values, cow salvage values, and net return per cow. They determined that if the replacement heifer value was $750, the salvage value was $600 and the net return per year was $75, it would require four years of production for a replacement heifer to reach breakeven (Table 4.2). If young cows leave the herd before this there is a net loss. In the case of the study by Whittier et al. (1995), 13% more cows reached breakeven due to early weaning management during their first lactation.

Table 4.2 Breakeven ownership period of a cow (years).[a]

Replacement heifer value	**Salvage value of culled cow**	**Net Return/Cow** **$75**	**$150**	**$225**
$750	$600	4	2	1
	$700	2	1	1
	$800	1	1	1
$900	$600	8	3	2
	$700	6	2	2
	$800	5	2	1
$1050	$600	14	5	3
	$700	12	4	3
	$800	10	3	2

[a] Dalsted and Gutierrez 1989

[b] 90% weaning rate and 5% discount rate were used by Dalsted and Gutierrez (1989)

Longevity and improved conception rates of beef cows are key economic parameters that will affect overall profitability. In a partial budget the economic value will depend upon the age of the breeding females and whether or not lactational stress will reduce BCS enough to reduce conception rates.

4.5 Effects of cow body condition on winter feed costs

In Alberta, winter-feeding is one of the most significant costs in cow/calf production, averaging 30-35% of total production costs (Alberta Agriculture 1999). Fat cows usually need only small quantities of supplements, while thin cows need large quantities of supplements high in energy and protein. Researchers in Minnesota (Thompson et al. 1983) reported a 6-10% increase in energy requirement for maintaining thin cows through the winter in a cold environment, compared to cows in moderate to good body condition. More recently Koberstein et al. (2001) at the University of Alberta, concluded that thin cows required $0.31 / 450 kg / day more feed input over cows in moderate to fat condition. Therefore a cost savings could result from having cows enter the winter in better body condition.

A great deal of research has been done on early weaning and its effect on forage intake and supplemental feed costs (Lusby et al. 1981; Peterson et al. 1987; Myers et al. 1999a). The results are highly dependent on the quality and quantity of forage and body condition of the cows. As discussed in Chapter 1 and 2, early weaning during times of drought is an accepted practice for rationing a limited forage supply. During drought the availability and cost of forage can be very high when a significant proportion of the winter feed must be purchased.

Peterson et al. (1987) conducted research on early (110 day) versus normally (220 day) weaned fall calving cows; they estimated the hay consumption by the early weaned dams was 45.3% less than normal weaned cows. In this same study when TDN consumption for both the cow and the calf was compared, early-weaned cow/calf pairs consumed 20.4% less TDN than normal weaned cow/calf pairs. Work in Oklahoma by Purvis et al. (1995) found similar findings, in that early weaned cows consumed approximately 1% less of their body weight in forage than normal weaned cows after they were weaned. Both trials found no difference in pregnancy rates and concluded that the advantage of early weaning mature cows was through stretching the forage supply and reducing winter-feed costs.

Not only will early weaning stretch the forage supply, but it will also affect the amount of supplemental feed fed during the wintering months. Typically drought conditions not only decrease available forage supply but also increase the cost of harvested forages. Thompson et al. (1983) studied the effects of varying levels of winter-feeding and body condition on Hereford x Angus cows. Cows in body condition score 3.5 (scale 1 – 5) required 20% less feed than cows in a condition score 2.5. Similarly, Wright (1988) estimated that allowing a cow to change condition score from a 3 to 2.5 from October to March reduced the winter feed costs and improved economic returns by 17%. Wright (1988) compared the effects of early weaning on the effects of maintaining low body conditioned cows. They found that early weaning returned $20.57 USD / head more than maintaining thin cows and trying to recondition them before calving. The work by Koberstein et al. (2001) concluded that cows in good to excellent body condition required $50 / head less for feed than cows classified as thin during a normal winter feed year. Drought as a factor could more than double the savings in winter feed costs reported by Koberstein et al. (2001) due to market pressures of supply and demand that increase winter feed costs.

4.6 The economic value of cow body condition on calf vigour:

Intake and absorption of antibodies from the dam's colostrum are vital for calf survival and health. In a University of Georgia study, researchers Vann and Baker (2001) looked at the effect of immunoglobulin G (IgG) and immunoglobulin M (IgM) concentrations in the serum of calves at 24 hrs of age on their monthly weights up to the time of weaning. They found that pre calving cow body condition had major effects on the levels of immunoglobulin G and M present in colostrum (Table 4.4). In the Georgia study serum IgG levels were classified as superior, average or inferior. Calves in the superior and average groups were significantly heavier at all weigh periods than those in the inferior group. At weaning the superior group was 31 lb heavier than the average group and 64 lb heavier than the inferior group. The results of the University of Georgia study verify the importance of pre calving body condition and its effect on colostrum quality. Assuming $1.25 / lb of calf at weaning, the economic difference would be $39.13 less per head for the group classified as average and $80.43 less per head for the group classified as inferior.

Table 4.3 The effect of cow body condition score on serum levels of immunoglobulin M and G immediately post partum. Vann and Baker (2001)

	Cow body condition score[a]			
Item	2	2.5	3	3.5
IgM* (mg/dl)	146	157	193	304
IgG** (mg/dl)	1998	2179	2310	2349

[a] 1 to 5 scale; where 1 is emaciated and 5 grossly fat
*immunoglobulin M
**immunoglobulin G

4.7 Economics related to calf performance:

Although the benefits of early weaning on improving cow body condition and subsequently improving reproduction and reducing feed inputs have been recognized for many years (Peterson et al. 1987; Adams et al. 1994; Faulkner et al. 1994), the limiting factor has been knowledge about the management of the early-weaned calf (Lusby et al. 1996). Considerations for weaning must take into account the total losses and gains to the cow calf enterprise. If calves are sold at the point of weaning, will the reduction in annual cow costs be greater than the reduction in sale value? King (1995) found that direct marketing calves at the point of early weaning would require a $5.24 to $18.24 USD / cwt premium for calves marketed 30 to 90 lb below normal weaning weight to offset income losses due to reduced marketable product.

The potential exists to offset losses in decreased marketable product through retained ownership until traditional weaning time or even ownership through to slaughter.

Another alternative would be the marketing of feed bunk broke and pre immunized calves.

Growth rates for weaned and unweaned calves will depend on many factors. These include: pasture forage quality/quantity, calf age, gender and genetics, and the ability of the dam to sustain lactation. Gifford (1949) found the correlations between dam's daily milk production and calf weight to be 0.60, 0.71, 0.52, and 0.35 for the first, second, third and fourth months of lactation, respectively. Correlations between the same traits for the following four months were smaller and nonsignificant. He concluded that growth potential may not be maximized by continuing to nurse the dam beyond four months of age. Most researchers (Lusby et al. 1981; Myers et al. 1999b; Short et al. 2000) have concluded that weaning calves at or beyond 120 days of age will have little negative impact on the rates of gain as compared to normally weaned calves. Weaning calves earlier than 120 days of age requires more nutritional management, and although rates of gain can be kept similar to the normally weaned calves, more often than not the weight gains are depressed (by 20-25%) till the calves reach 120 days of age. In addition to the expense of reduced gains there can also be additional costs due to the feed supplements needed to manage these early weaned calves. All these variables need to be taken into account when determining the age of weaning and which backgrounding system will optimize the return on investment for the manager. Although early weaned calves can be backgrounded on pasture; feedlot / dry lot programs to date, have proven to be the most effective in promoting near "normal" rates of gain (Lusby, 1996). Young calves can be very efficient on high-concentrate rations and dry matter conversions of 4:1 are possible up to weights of about 500 lb. However, feeding in a feedlot environment comes with a cost of not only the feed but the cost of yardage.

4.8 Economic variables related to feedlot yardage

Yardage is defined as the costs associated with the upkeep, feed delivery, manure removal, labor, interest costs and facility depreciation of a feeding and confinement facility. Alberta Agriculture (2000) surveyed 38 cow/calf producers that wintered an average of 158 cows, and found that the average yardage cost on a per cow basis was $0.67/ head/day (Table 4.4). Although the yardage was based on wintering mature beef cows, calf yardage costs can still be significant. In Alberta, feedlot yardage costs for calves will range from $0.30 to $0.45/hd/day (Alberta Feedlot Manual, 1996). If animals are gaining less than 2 lb/day this may add significantly to the cost of gain of that animal. Feeding programs for young (2- month old) calves need to be "growing programs" that hold daily gains to levels similar to those achieved on the cow. These rates of gain will generally range in the 2.0 to 2.5 lb/day range depending on frame size and growth potential of the calves. At a 2.0 lb/day rate of gain and yardage of $0.40/hd/day, there would be a $22/head expense for calves weaned at 150 days and backgrounded to the normal weaning age of 205 days. In other words yardage would cost $0.20/lb of gain. There is potential to reduce the cost of yardage on a per pound basis simply by increasing the average daily gain of the calves. This must be done however in balance with the breed type and frame score of the calves; otherwise, full-fed early weaned calves may get fat too early and not finish at acceptable slaughter weights.

Table 4.4 Cow/Calf enterprise yardage costs. Alberta Agriculture (2000)

	$/Cow wintered	$/head/day
Variable costs		
Fuel	13.67	0.07
Repairs – machinery	12.46	0.06
Repairs – buildings	10.24	0.05
Utilities	6.84	0.03
Custom Work	5.57	0.03
Operating Interest	8.13	0.04
Paid labour and benefits	2.16	0.01
Unpaid labour	34.65	0.17
Total variable costs	93.72	0.47
Capital costs		
Equip and Building Depreciation.	33.82	0.17
Capital interest paid	5.73	0.03
Total capital costs	39.54	0.20
Total cash costs	64.54	0.33
Total production costs	133.27	0.67

More economical than feedlot backgrounding would be a pastue feeding program, in which manure removal and facility depreciation would be minimal (Pordomingo 2002). The difficulty with pasture backgrounding programs is that for very young calves (< 80 days of age) gains may be insufficient due to the high roughage composition and physical limitations within the calf to deal with them. A recent Argentine study (Pordomingo 2002) found that, provided pasture resources were not limited in quality and quantity, they would work in maintaining similar weight gains to those achieved in a dry lot situation, where calves were fed a complete mixed ration.

Researchers at Oklahoma have also researched forage systems that may provide an answer for backgrounding early weaned calves, namely wheat pasture. In an experiment conducted by Lusby (1996), 55 calves born in September and October were weaned at 90 days, held in dry lot for two weeks on prairie hay and 2 lb of protein pellets, and then moved to wheat pasture. Calves gained about 2 lb/day on wheat throughout the grazing period without supplementation of concentrates. Virtually all cows rebred with minimal supplement on native range. This system offered the potential to reduce winter feed costs for the cows, increasing stocking rates on the native pasture while minimizing labor and facility overhead. Most Alberta cow/calf producers have access to higher quality pastures in the fall (ie alfalfa/brome hay and pastures). The results from both the Argentine and Oklahoma study would be transferable to Alberta, provided cow/calf producers plan ahead and allocate these high quality pastures for the early weaned calves and not the cow herd.

Drought and feed shortages will always be major factors that initiate early weaning. As much as pasture backgrounding could hold the answer to reducing yardage and the cost of rearing early weaned calves, more often than not the dry lot feeding program will be the method chosen by producers during drought situations because of the lack of pasture resources. Likewise, feedloting very early weaned calves that are under 90 days of age will allow for better health and feed consumption monitoring (Lusby, 1996; Myers et al. 1999a; Short et al. 2000).

Calves that are destined for slaughter will need to be moved to progressively higher energy diets over time. Moving calves from a high rate of gain in a dry lot situation back to pasture will result in poor gains. Therefore, calves raised in feedlot to normal weaning age on mixed rations need to be moved to nutritional programs with good gain potential for finishing.

4.9 Economics variables related to calf health

Although health is often difficult to quantify, many researchers (Fluharty et al. 1996; Myers et al. 1999a) have shown weaning age has an important role, and factor in the health of calves during backgrounding and through to the finishing period. After slaughter the impact of weaning can still be quantified in terms of differences in carcass qualities and feedlot feed efficiency (Grimes et al. 1991; Myers et al. 1999a). Myers et al. (1999a) studied the health of steers that were 1) early weaned (EW; 165 d), 2) normal weaned creep (NWC; 215 d) where animals had access to creep feed for 50 days prior to weaning or 3) normal weaned (NM; 215 d) without creep feed. They found that EW steers had 84% less respiratory morbidity when compared with the average of NWC and NW steers. Another study by Meyers et al. (1999b) looked at the effects of weaning on the health of 90d, 152d, and 215d weaned steers. In it they observed a quadratic response for the percentage of steers treated for respiratory morbidity and digestive morbidity. Early weaned (152d) had the lowest morbidity among treatments. In both experiments the authors concluded that the high percentage of respiratory morbidity in the normal weaned treatments may have been attributable to the effects of cooler weather in the fall.

From 1991 to 1996 animal health and feedlot performance data were collected from the Texas A&M "Ranch to Rail" program; this was an extension program started for cow/calf producers to better understand the feedlot potential for their 210 day old weaned calves. Calves were received and fed at a number of feedlots throughout Texas and classified as either sick or healthy at entry; these animals were then followed through to slaughter and evaluated for feedlot and carcass performance as well as economic returns (Table 4.5). The average net return for steers across the program was $37.45, however, once the steers were classified as sick or healthy the numbers dramatically changed (Henderson, 1997).

Table 4.5 The impact of health on performance, profits and carcass quality [a]

	Sick	Healthy
Head	3202	9393
Death Loss	3.40%	0.50%
Average Daily Gain	2.78	2.96
Total cost / lb gain	$65.96	$56.68
Medicine cost per head	$31.33	$0.00
Net return per head	($31.97)	61.23
Quality Grade		
Choice	29%	39%
Select	63%	56%
Standard	8%	5%

Data from Texas A & M Ranch to Rail Program 1991 - 1996

Drovers Journal; August, 1997

[a] Costs and returns quoted in USD

In the Texas A&M Ranch to rail program 25% of calves at entry were classified as sick. The average death loss, treatment cost and costs of gain were all significantly greater for the sick calves compared to the calves classified as healthy upon induction. Net returns for the calves classified as sick were -$31.97 per head compared to $61.23 USD for healthy calves. Not factored into the returns were the differences in bonuses or discounts for the various carcass qualities. If carcass quality had been factored into the equation the range for returns would have been from a positive $307 /head to a negative $310 per head (Henderson, 1997). Performance factors for average daily gain and feed efficiency were important at influencing the impact on the feed cost of gain; however, the impact on health and the ability of steers to express their genetic potential beyond just the cost of medicine was even more important.

4.10 Economic variables related to carcass quality:

In today's competitive value-based marketing system, raising cattle that produce high quality, uniform beef, could enhance the competitive ability of the beef industry. Beef industry focus is for finished animals to have a greater lean to fat ratio or carcass cutability, while at the same time increasing the amount of intramuscular fat or marbling. The age at which weaning occurs can have a profound effect on carcass quality. Myers et al. (1999a) studied the effect of three weaning management systems and three breed types on steer and carcass performance for two years. During the two years of study they not only found that the EW calves gained faster that the average of NWC and NW steers, but that the EW steers also had lower intakes and better feed conversions than the average of NWC and NW steers (Table 4.6). Weaning treatment affected marbling scores, with EW steers having greater marbling scores compared with the average of NWC and NW steers. They also found that early weaning improved the percentage of steers grading Average Choice or higher by 40%.

Research by Wertz et al. (2002) also found that by placing calves onto a high concentrate diet sooner they were able to increase the level of intramuscular fat relative to subcutaneous fat. They concluded that calves placed on feed sooner were likely to reach quality grades that were eligible for grid premiums before they attained a yield discount. Story et al. (2000) also found that early weaned (150 d) steer calves had greater daily gains, feed conversion, marbling scores and carcass yields than normal weaned (210 d) and late weaned (270 d) steers. These improvements in finishing characteristics resulted in feedlot returns of $75.36 for early weaned, $62.16 for normal weaned and $10.09 for the late weaned treatments. The authors concluded however that even though the early weaned steers had generated the most revenue for the feedlot phase, as a system it was not sufficient to offset the loss of revenue that occurred at weaning. They concluded that the majority of the cow/calf production costs are incurred by the time the calf is 150 d of age. The early weaned calves weighed less at weaning than the normal weaned and late weaned and so there is not as much money generated to offset the cow costs. They concluded that to maximize the benefits of early weaning, retained ownership was needed to increase the profit potential from this management system.

Table 4.6 Effects of three weaning management systems on steer performance and carcass quality. Myers et al. (1999a)

	Weaning Treatment			
Item	early weaned	normal weaned creep	normal weaned	SEM
No of steers	48	55	64	
Initial weight kg.	149	140	144	5
Slaughter Weight, kg.	493	478	470	7
Days in Feedlot	164	213	213	2
ADG, kg				
177-231 d	1.44	.82	.62	0.05
231-443 d	1.28	1.38	1.38	.02
Overall	1.31	1.27	1.22	.02
DMI, kg/d	7.70	8.20	8.12	.11
Gain/Feed	0.170	0.155	0.151	.003
Rib eye area cm^2	75.4	74.5	75.0	1.0
Yield Grade 1, %	12	5	16	5
Yield Grade 2, %	49	66	57	7
Yield Grade 3, %	39	29	27	5
Marbling score	1,168	1,124	1,122	13
≥Choice, %	95	87	91	4
≥Avg. Choice, %	81	58	58	6
≥Prime, %	15	10	2	4

4.11 Making economic decisions

As identified in the previous sections, there are many factors and variables that need to be considered when weaning. The resources of land, associated improvements, capital and labor must be organized to form the best combination that will optimize returns to the available set of resources. The decision of when to wean must be based upon combining the available resources and knowledge to best achieve the desired goals and objectives of the farm business.

The problems of resource use and allocation involve the application of five economic principles (Jobes, 1990). They are:

1) Adding units of an input as long as the value of the resulting output or added returns is greater than the added cost; thereby answering the question how much to produce?
2) Substituting one input for another as long as the cost of the added input is less than the cost of the input which is replaced and the output is maintained; this answers the issue of, how to produce it?
3) Substituting one product for another as long as the value of the added output is greater than the value of the output that is replaced and the cost is constant; what to produce?
4) Using each unit of resource where and when it gives the greatest returns when resources are limited; where to produce?
5) Basing comparisons upon discounted values when considering different time periods and/or elements of risk; when to produce?

The first three principles relate to situations where unlimited resources are available and there is perfect knowledge and the last two where resources are limited and there is imperfect knowledge. The budget process can incorporate any one or all of these principles. No one type of budget is tied to any particular principle. There are three basic types of budgets that can be used in the farm business management process. All three have commonalities in that, if properly defined and used, the format permits the use of economic logic to answer the question of what, how much, and when resources should be used. The three types of budgets are:

1) Whole-farm budget
2) Enterprise budget
3) Partial budget

The Whole Farm Budget is a classified and detailed summary of the major physical and financial features of the entire farm business. Whole farm budgets identify the components of the business and determine the relationships among the different parts, both individually and as a whole. Whole farm budgeting looks at time as it pertains to the future. It is the best tool to analyze the whole farm business and the progress towards the goals and objectives.

The Partial Budget is useful in analyzing the effects of a change from an existing plan. The budget only considers revenue and expense items that will change with a defined change in the plan. Time is harder to capture within a partial budget analysis.

The Enterprise Budget is a statement of what generally is expected from a set of particular production practices when producing a specified amount of product. It is useful in analyzing the potential effects of a change from an existing plan. It consists of a statement of projected revenues and expenses incurred in the production process. The enterprise budget documents variable and fixed costs and is useful in calculating projected profitability and breakeven values.

Although early weaning is a decision and management tool that can affect the whole farm budget; enterprise budgeting and breakeven analysis are most appropriately suited to answering the questions of time of weaning.

As previously described in this thesis, weaning cannot only affect the cost of production on the cow calf enterprise but can also affect its revenues if calves are sold immediately at weaning (King, 1995). Although some costs may be reduced, they may not be great enough to offset the reduced incomes. Story et al. (2000) found that the majority of the cow costs were incurred by the time the calf was 150 d of age. Early-weaning reduced the weaning weight sold compared to normal and (or) late weaning and although the price per unit of weight was greater for the lighter-weight calf, there was not enough total money generated to offset the cow costs. They concluded that the early-weaned calf needed to be retained after weaning to increase the profit potential for this management system. In fact, for the feedlot phase of their study the early-weaned steer generated the most revenue. Story et al. (2000) concluded that what needed to be done, was to look at the management system as a whole through enterprise budgeting and combine the profit/loss of the cow side of the equation with the profit/loss of the feeding side of the equation.

The enterprise budget should contain all variable and fixed costs associated with the defined enterprise. It should also contain the returns from the sale of those products. A cow / calf system may have several enterprises; not only would there be a cow enterprise but it may include a forage enterprise for the grazing aspects, a haying enterprise for the winter feeding needs, a backgrounding enterprise once the calves are weaned, and finally, perhaps a feedlot enterprise for finishing the animals. In the case of early weaning several enterprises will need to be looked at to get a true picture of the ramifications and roles early weaning can play for the whole farm budgeting process.

Enterprise budgeting would include all the inputs and outputs used in one production cycle of the operation (Jobes, 1990). The enterprise budget for weaning would include feed, yardage, interest, veterinary expenses, morbidity and mortality. It would also contain the values and sales of the cattle transactions as they move from one enterprise to the next. Benefits such as extension of the pasture carrying capacity, reductions in cow winter-feed costs, and perhaps improvements in future conception rates would also be factors that need to be considered.

4.12 Budget limitations and risk

Careful evaluation of the resource situation must precede the drawing of inferences for enterprise budgeting. Every farm and ranch will have different resources and management plans; as a result, these differences in resources and organization must be considered and adequately accounted for to be reliable and useful (Jobes, 1990).

Production and marketing risks will limit budget reliability. "Best estimates" should be used to develop budgets for use in farm business analysis. High degrees of variability create risk to management and can put pressure on the reliability of the estimates used in the enterprise budgets. An element of risk should be considered when determining the solutions that best meet the goals and objective of a cow calf operation. A discount factor should also be considered to account for risk.

The value of the risk factor will vary among cow/calf operations. Depending on the management change, the steeper the learning curve the greater the chances for failure (Butler, 1996). An acceptable risk factor or rate of return for changing the date of weaning would be the rate paid to borrow money or a rate. (Butler, 1996).

4.13 Breakeven analysis

The decision to sell at weaning, background, or to finish calves should be reviewed constantly. Many economic and production researchers (Lusby et al. 1981; Myers et al. 1999b; Short et al. 2000) have concluded that calves will need to be backgrounded to recoup the loss of sale weight if the calves are early weaned.

Further to the enterprise budget, breakeven analysis can be used to draw conclusions as to feasibility of the management change. Breakeven analysis can help in the decision of what an alternative will cost and what is needed to recoup the investment specific to the operation. In the case of weaning as a management tool it is a way of comparing both marketing and backgrounding alternatives; in which both a cost difference and performance difference may occur through feedloting or pasture back grounding.

Breakeven analysis requires esstimates of calf weights, growth potential, shrink, feed costs, market values and yardage costs. Breakevens analysis will assist in determining the points at which the decision to change can be made.

4.14 Implications and conclusions

Market values for beef fluctuate, but so too do production resources such as pasture and feed. Weather and forage production variables are dynamic and can change from one year to the next. Unique as well are the circumstances of each cow/calf operation. These circumstances will include available resources, cost of production values and the financial stability and ability to absorb risk.

From a biological aspect, altered weaning dates affect cow body condition and body weight. These changes will subsequently affect cost of production through changes in winter feed and pasture requirements as well as conception rates and cow depreciation. On the other side of the equation, weaning will affect calf growth rates, nutrition and management.

To fully understand the ramifications of altered weaning dates an enterprise budgets combined with breakeven analysis needs to be done on a yearly basis to decide the best combinations of resource allocation and weaning date. In the next chapter a budget enterprises coupled with a breakeven analysis from the results of Chapter 3 will be presented. This will help to evaluate the optimum combination of weaning dates and management system.

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CHAPTER 5

THE EFFECT OF WEANING TREATMENT ON COW/CALF PRODUCTION ECONOMICS

5.1 Introduction

Changing calving and (or) weaning dates can result in improved herd performance (Lusby et al. 1981; Adams et al. 1994; Whittier, 1995). An increase in profit potential may be realized by reducing annual winter feed and pasture costs, increasing herd reproductive performance or through alternative calf marketing options (Lusby et al. 1981; Whittier, 1995; Meyers et al. 1999b). In the aspen parkland of western Canada, feeding and managing the beef cow through the winter is the largest cost to beef production, accounting for 60-65% of total costs of production in a cow/calf operation (McCartney et al. 2004).

Early weaning of calves can result in heavier calves compared to normal weaning (seven months) (Peterson et al. 1987; Makarechian et al. 1988). Research studies have evaluated cow and calf performance when calves were weaned at less than 150 d of age (Peterson et al. 1987; Gill et al. 1993; Purvis et al. 1996). Economic modeling of the cow/calf enterprise by Spreen and Laughlin (1986) indicated that weaning calves at six months of age in the mid west of the United States resulted in the greatest value for gross income. There are limited published data that have evaluated the economic production characteristics of the cow and calf beyond the point of weaning. The objective of this chapter is to analyze the production economics of the biological data reported in Chapter 3 and determine the economic effects of retained ownership from weaning calves at 72, 132, or 192 d of age.

The hypothesis - Using enterprise budgets and breakeven analysis to evaluate the production economics of retained ownership from the biological data reported in Chapter 3, there are no economic differences between very early wean (VEW: 72d), early weaning (EW; 132d) and normal weaning (NW; 192d) treatments.

5.2 Materials and Methods

5.2.1 Cow/Calf enterprise

This study was conducted at the University of Alberta, Kinsella Research Station located in East Central Alberta. The study was conducted from March 30, 1998 to March 30, 2001 and involved 240 Kinsella Hybrid (Berg et al. 1986) spring-calving cows (BW±SE: 605±8 kg; BCS±SE: 2.6±0.06 at March 30, 1998), assigned to one of three weaning management groups based on BW, BCS and age. The three weaning treatments were:

- very early weaning (VEW: 72±12 d age; n = 96; weaned July 9)
- early weaning (EW: 132±12 d age; n = 92; September 9)
- normal weaning (NW: 193±12 d age; n = 50; November 9).

Cows remained in their assigned weaning treatments for the three years unless they were culled from the herd for reproductive failure or dystocia, poor feet, BCS less than 1.5, low udder score or loss of calf.

After normal weaning (November 9) each year, cows were managed as a group on range, until the grazing season ended and then they were assigned to one of three winter management treatments. The three winter management treatments were Underfed (UF: 85% recommended NRC), Normally Fed (NF: 100% recommended NRC) and Overfed (OF: 115% recommended NRC). The assignment of weaning and management groups was a 3 x 3 factorial arrangement with three weaning treatments (VEW; EW; NW) and three winter feeding treatments (UF; NF; OF). During the spring and summer, all cows were managed as a single group and grazed cool-season native fescue rangeland *(Festuca hall* L.) and cool-season smooth brome and blue grass *(Bromus inermis* L., *Poa pratensis* L.) pastures. Weaned cows remained with the rest of the herd until winter-feeding began.

The amount of hay, supplement, and other inputs specifically associated with each weaning management group were recorded. Cows that fell below 1.5 body condition score (five point scale: 1 = emaciated, 5 = grossly fat; Lowman et al. 1973) were removed from the trial as culls. All cows were weighed and body condition scored one month prior to calving, at each weaning period and just prior to winter feeding.

Each year during the breeding season, all cows were managed in the same pastures and exposed to yearling Kinsella Hybrid bulls (Berg et al. 1986) for a 45-d breeding season beginning on July 9 (the day of very early weaning) and ending August 23 each year. Bull to cow ratio was 1 to 25. Calves were identified and weighed on a spring-loaded scale within 24 hr after calving. Cows were scored for ease of calving on a scale of 0 to 5 (0 = no assistance; 1 = slight assistance; 2 = puller used easily; 3 = puller used with difficulty; 4 = veterinarian required; and 5 = caesarean birth). Mammary systems were scored (1 = small ideal teats; 2 = ideal teats; 3 = large teats; 4 = very large (bottle) teats; 5 = pendulous udder; 6 = one or two blind teats; 7 = mastitis) within 24 hr after calving. Pregnancy rates were determined in November by rectal palpation. Cows that were removed from the experiment were not replaced.

Production input quantities associated with each weaning management treatment was included for economic analysis. Amounts of hay, grain, protein supplement, salt and mineral fed were logged and charged to each group. Feed costs were determined from values reported by Agriculture Financial Services Corporation (2004) for the periods 1998, 1999, 2000 and 2001. Labor, overhead and operating costs associated with feeding were determined from data reported by Kaliel et al. (2004) in the Benchmarks for Alberta Producers: Aspen Parkland Region. Grazing costs were based on the opportunity value of an animal unit month (AUM) in the eastern central Alberta Aspen Parkland Region (AFSC 2004). Grazing costs were calculated based on the AUM value of a lactating cow and adjusted for weaned cows and calves. Cow culling costs were determined using the difference between the salvage value for cull cows and the value of the bred replacement heifers and then multiplying that by the culling rate for the perspective treatment. The depreciation cost for each perspective treatment was then added as an expense to each cow in that particular treatment.

5.2.2 Finishing enterprise

Very early and early-weaned steers were either backgrounded on pasture or in feedlot confined feeding, until the last treatment was weaned. Production costs associated with these backgrounding treatments included grazing costs, supplements, feed and yardage. Following weaning of the final (NW) treatment all steers were moved into the feedlot, and further production costs for feed, bedding, yardage, interest and veterinary charges were documented. Steers were fed to an intended end point of 1 cm backfat thickness, which was estimated visually by experienced feedlot personnel. The economic analysis evaluated the market prices for weaned and finished steers, weaning and finishing weight, and days on feed. Market prices used to value weaned and finished steers, were the four-year average (1998-2001) prices reported by Canfax (2004), specific to the time period in which the calves were weaned and marketed, and specific to the appropriate weight ranges. Four-year average prices for feedstuffs (AFSC, 2004) from the east central Alberta aspen parkland region were used in ration pricing. Ration costs were separated into backgrounding and finishing costs. Total feed costs for each period were based on dry matter intake, feed efficiency, days on feed, and ration cost per kilogram. Gross income per steer, feed, yardage, veterinary, trucking, interest expense, and net income per steer were also calculated.

5.2.3 Heifer backgrounding enterprise

Very early and early weaned heifer calves were backgrounded on pasture with ad libitum access to oats creepfeed until the last treatment was weaned. Upon weaning of the final treatment, heifers were backgrounded in confinement until May 20 each year. Heifers were not retained past this period and were removed from the experiment upon completion of blood sampling for the determination of cyclicity. Grazing costs were adjusted to animal weight and animal classification and based on the average cost of an AUM in the east central Alberta aspen parkland region (AFSC, 2004). All supplements, feed, bedding, labor and yardage costs associated with backgrounding of the heifers were documented and used in the economic analysis. As with the steers, four-year average market prices (1998-2001) for feedstuffs were used to cost the ration (AFSC, 2004). Labor and yardage costs associated with feeding the heifers were charged according to data reported by Kaliel et al. (2000). Live weight market prices used to value weaned and backgrounded heifers were four-year average prices for the period 1998-2001 (Canfax,

2004) in which the calves were weaned and marketed, and specific to the appropriate weight ranges.

5.2.4 System evaluation

Net revenue or loss per cow for each weaning treatment was evaluated based on the cost/return data from the cow/calf, replacement heifer backgrounding, and finishing enterprises. Income was generated by sale of finished steers and backgrounded heifers. The assigned calf value for each weaning management system was based on the weight of the calves at each weaning period and the value of steers and heifers at the point of weaning. Prices were expressed as $value / 45 kg increment. Labor for checking cattle while they were grazing was included as part of the AUM grazing cost, whereas feedlot labor was considered part of the yardage charge. Net revenues at slaughter were based on actual live slaughter weights and four-year average prices for finished cattle at the specific time of year at slaughter. Cattle prices and feed costs used in the enterprise analysis are listed in Table 5.1.

Table 5.1 Input prices used in all enterprise analysis over the three-year period of the study.

	Unit	Unit Cost
Feed[a]		
First cut grass /alf. hay	$/ 1000 kg	$73.00
Second cut mixed hay	$/ 1000 kg	$85.00
Barley grain	$/ 1000 kg	$96.00
Oat grain	$/ 1000 kg	$78.58
Calf starter	$/ 1000 kg	$260.00
Summer pasture	$/AUM	$23.50
Steer[b]		
125 – 174 kg	$ / 45 kg	$158.00
175 – 224 kg	$ / 45 kg	$138.00
225 – 274 kg	$ / 45 kg	$130.00
275 – 349 kg	$ / 45 kg	$122.00
350 - 424 kg	$ / 45 kg	$114.00
Slaughter wt.	$ / 45 kg	$94.00
Heifers[b]		
125 – 174 kg	$ / 45 kg	$150.00
175 – 224 kg	$ / 45 kg	$130.00
225 – 274 kg	$ / 45 kg	$122.00
275 – 349 kg	$ / 45 kg	$112.00
350 - 424 kg	$ / 45 kg	$105.00
Cull Cow[b]	$ / 45 kg	$55.00

[a] Prices reported by AFSC 2004
[b] Prices reported by Canfax 2004

5.2.5 Breakeven analysis

The weaned breakeven was calculated in the following manner: The cow cost to produce the weaned calf divided the average steer calf weight at weaning.

The NW breakeven was calculated by adding the cows cost to produce a weaned calf plus the backgrounding expenses to grow the steer to 192 days of age divided by the weight of the steer at 192 d.

The economic breakeven for the finished steer was calculated by adding the total cost of finishing the steer plus the value of steer calf at the time of weaning, and the sum was divided by the slaughter weight. The opportunity cost for the steer calf at weaning was determined by multiplying the average weaning weight by the four-year average market price for the month in which they were weaned (Canfax, 2004).

Breakevens for the finished steer on a financial basis was calculated by adding the total costs of the finished steer plus the calf valued at its production costs (cow costs to produce the weaned calf), and the sum was divided by the slaughter weight. All breakevens were sale price breakevens.

The weaned breakeven for the heifers was calculated by adding the annual cow cost and dividing it by the average heifer calf weight at weaning.

The NW breakeven was calculated by adding the cows cost to produce a weaned calf plus the backgrounding expenses to grow the heifer to 192 days of age divided by the weight of the heifer at 192 d.

Backgrounded economic breakevens for the heifers were calculated by adding the total costs of the backgrounded heifer plus the heifer calf valued at weaning at its opportunity value, and the sum divided by final weight. The opportunity cost for the heifer calf at weaning was determined by multiplying the average weaning weight by the four-year average market price for the month in which they were weaned (Canfax, 2004). Breakeven for the backgrounded heifer on a financial basis was calculated by adding the total costs of the backgrounded heifer plus her value at production cost (cow costs to produce the weaned calf), and the sum was divided by the final weight.

5.2.6 Statistical analysis

All data were analyzed using the Proc Mixed procedure of SAS (1996). This study was conducted over three years and designed as a carry-over experiment that allowed for the analysis of any carry-over effect due to the previous year's weaning management assignment. All performance, reproductive, and economic data were analyzed using treatment groups as experimental units. The model included weaning treatment, backgrounding treatment and year.

5.2.7 Economic analysis

The economic analysis first evaluated yearly costs per cow; this was determined by dividing the total costs by the weaning ratio to take into account the expenses incurred from cows that failed to wean a calf (Table 5.2). After the costs of production for maintaining the cow were determined the net contribution of weaned calf sales was calculated (Table 5.3).

Economic analysis of the realized net profit or loss of each weaning treatment as the heifers or steers went through the respective backgrounding and (or) finishing segments were also determined (Table 5.4, 5.5). Finally, all the positive and negative contributions to the different enterprises (cow/calf, backgrounding and feedlot) were tallied to determine the net contribution back to assets (Table 5.6). The economic analysis also evaluated the net revenue or loss to the cow/calf enterprise from the sale of backgrounded and weaned calves at normal weaning (192 d), these results are presented in Table 5.7.

Table 5.2 Yearly cow costs including interest, depreciation, pasture, winter feed, and yardage for VEW, EW and NW treatments averaged over the three-year period[1].

	Treatment			
	VEW	EW	NW	SEM
Winter feed and bedding [2]	\$140.44	\$159.17	\$187.26	
Pasture [3]	\$129.83	\$147.14	\$173.11	
Total feed costs	\$270.27[a]	\$306.31[b]	\$360.37[c]	6.73
Veterinary and medicine	\$20.00	\$20.00	\$20.00	
Breeding fees/bull rental	\$40.00	\$40.00	\$40.00	
Repairs - machine corrals and buildings	\$35.00	\$35.00	\$35.00	
Utilities, fuel and miscellaneous expenses	\$25.00	\$25.00	\$25.00	
Custom work and labor	\$166.72	\$166.72	\$166.72	
Total vet, breeding and yardage	\$286.72	\$286.72	\$286.72	
Cow culling expense [4]	\$60.50[a]	\$77.55[b]	\$84.31[c]	4.36
Calf weaning %	99%	99%	98%	
Total costs / Calf Weaned %	\$623.72[a]	\$677.35[b]	\$746.32[c]	8.25

[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned

[2] Based on hay at \$.073/kg, barley at \$.096/kg, protein supplement at \$.239/kg, salt and mineral at \$.738/kg and adjusted using data from Koberstein et al. (1999)

[3] Grazing cost based on \$23.50/ AUM; Total cost of grazing adjusted for weaned versus lactating cows. i.e. pasture costs for weaned cows reduced by 30%; Landblom et al. (2005)

[4] Cow culling expense was calculated using the average culling rate over the three years and multiplying that by the difference in value between a cull cow and bred replacement (Canfax 2004)

[a,b,c] Numbers within a row with differing letters differ *(P <0.05)*

5.3 Results

5.3.1 Cow/Calf enterprise

Weaning treatment affected ($P<0.05$) the yearly cow costs on a per head basis. The reductions in expenses were achieved in three segments. The first expense that was directly reduced by weaning was annual pasture expenses; this was directly proportional to the length of time the cows were lactating and the AUM value adjusted to reflect those differences. A cow that is lactating and a cow that is weaned will have different forage consumption levels. This difference in pasture consumption is real, for a cow/calf operation it would either allow the opportunity for more cows to be grazed on the same land base or that the grazing resource would last longer and winter feeding could be delayed that much longer. For example EW and NW weaned cows nursed an average of 60 days longer than VEW cows. This resulted in a $17.31 projected grazing cost savings for VEW over EW cows and a $43.19 savings over NW cows for grazing expenses.

Another significant ($P<0.05$) difference in annual cow costs was winter feed requirements. As shown in previous research (Peterson et al. 1987, Meyers et al. 1999b) and found in this experiment, the earlier cows are weaned the greater their gain in BCS and BW. The result of the increases in BCS and BW can be a net benefit in winter feed savings because the cows will require less feed supplement during the winter feeding period. As reported in Chapter 3, weather patterns on the research station over the three winters were atypical and varied from excessive wind chill in some pastures to little or no snow in others. A lack of snow cover allowed some cows access to forage aftermath even in the middle of winter, making it impossible to control energy intakes. In addition wind chill exposure was more severe in some pastures than others complicating energy balances to such an extent that the validity of the results was in doubt. In an attempt to make the most out of the data relating to the expense of winter feed, a compilation of the ration that was fed to the different treatments and the data reported by Koberstein et al. (2001) on the impact of BCS on wintering feeding costs was used to model differences in winter feed costs. Using these values, the average winter feed costs were $140.44 for VEW; $159.17 for EW and $187.26 for NW cows over the three-year study period (Table 5.2).

The last difference among VEW, EW and NW treatments was cow culling rate. Cow culling expenses in this study were defined as the difference in value between a cull cow and a bred replacement animal. The total culling rate was calculated by taking the total culling rate for the total experiment and dividing it by the number of years of the trial. This percentage was then multiplied against the culling expense of the animal. Over the three-year experiment there was a higher culling rate ($P<0.05$) for EW and NW cows as compared to VEW cows. This resulted in an additional expense difference between treatments for this experiment. Total costs after the annual cow expenses were adjusted for weaning ratio were: VEW $623.72±8.25, EW $677.35.25±8.25, and NW $746.32±8.25 over the three year period. The difference between the lowest and the highest cost of production for annual cow cost of production was of $122.60.

Weaning treatment not only had significant effects ($P<0.05$) on annual cow production costs but also on gross sale receipts. The system analysis (Table 5.3) indicated that by selling calves at the time of weaning all weaning treatments realized a loss to the cow enterprise. Losses were greatest for VEW (-$211.64±8.81) followed by EW

(-$69.11±8.81) and closest to breakeven was NW (-$26.25±8.81). The net losses were significantly ($P<0.05$) different for all treatments.

Table 5.3 Net revenue or loss to the cow/calf enterprise from the sale of calves at the point of weaning.

	Treatment[1]			
	VEW	EW	NW	SEM
Annual cow costs / head[2]	$623.72	$677.35	$746.32	
Average weight at weaning, kg[3]	122	202	255	
Price received for calves at weaning, $/45 kg[4]	$152.00	$135.50	$127.00	
Calf market value at weaning / head	$412.08	$608.24	$719.67	
Net revenue or loss from sale of weaned calf	-$211.64^{a}	-$69.11^{b}	-$26.25^{c}	8.81

[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned
[2] Cow costs to produce weaned calf adjusted by the weaning ratio
[3] Average weights of steers and heifers at the time of weaning
[4] Combined average market price of weaned steers and heifers at the time of weaning; Canfax 2004
[a,b] Numbers within a row with differing letters differ ($P<0.05$)

5.3.2 Finishing enterprise

Feedlot phase net income per steer was calculated using the feed and performance parameters presented in Chapter 3. Using the four-year average market price (1998-2001) for the month in which the steers were weaned and 'marketed', all treatments indicated positive net revenues (Canfax, 2004). Feedlot phase net income differed ($P<0.05$) for all treatments (Table 5.4). It was greatest for the VEWP steers, followed by the VEWF and EWP, followed then by EWF and least for NW steers. Steer values (costs) were lowest for VEW treatments followed by EW and greatest for NW steer calves.

Table 5.4 Steer finishing costs including interest, depreciation, expenses of livestock, feed, and equipment for VEW, EW and NW treatments[1] averaged over the three-year period of the study.

	Treatment					
	VEWP	VEWF	EWP	EWF	NW	SEM
Weight at weaning, kg	126	126	209	209	270	
Market value at weaning, $/45 kg[2]	$158	$158	$141	$141	$131	
Value at weaning	$442.40	$442.40	$654.86	$654.86	$786.00	
ADG during backgrounding period	0.9	1.1	0.90	1.0	-	
Backgrounding period, d	123	123	61	61	0	
Weight at the end of backgrounding[3]	229	258	252	268	270	
Finished weight	537	554	562	577	572	
Market value at finish, $/45 kg	$94	$94	$94	$94	$94	
Gross income from finished steer	$1121.73	$1157.24	$1173.95	$1205.28	$1194.84	
Days on feed	178	175	177	175	176	
Costs associated with backgrounding						
Feed, pasture and supplements[5]	$58.50	$101.40	$37.83	$50.46	-	
Yardage[6]	-	$49.20	-	$24.40	-	
Costs associated with finishing						
Feed costs[5]	$232.37	$240.99	$202.31	$258.57	$238.21	
Bedding	$15.00	$15.00	$15.00	$15.00	$15.00	
Yardage[6]	$71.20	$70.00	$70.80	$70.00	$70.40	
Vet and induction	$10.00	$10.00	$10.00	$10.00	$10.00	
Trucking	$15.00	$15.00	$15.00	$15.00	$15.00	
Total operating interest[7]	$32.50	$33.74	$33.00	$34.19	$25.97	
Total operating costs	$434.57[b]	$535.33[d]	$383.94[a]	$477.62[c]	$374.58[a]	8.18
Net revenue / steer	$244.66[e]	$179.51[d]	$135.15[c]	$72.80[b]	$34.26[a]	8.74

[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normally Weaned steers

[2] Market price of steers at the time of weaning (72 d, 132d 192d); Canfax 2004

[3] Weights of steers at 192d

[4] Market price of steers at 192d; Canfax 2004

[5] Based on hay at $.073/kg, barley at $.096/kg, protein supplement at $.239/kg, salt and mineral at $.738/kg Ration costs were based on four-year average feedstuff prices, grazing cost based on calf AU equivalent and AUM priced at $23.50

[6] Yardage charged at $0.40 / steer / day

[7] 6% annual interest rate

[a,b,c,d,e] Numbers within a row with differing letters differ (*P* <0.05)

5.3.3 Heifer backgrounding enterprise

At the time of VEW there were no treatment differences in heifer weights (Table 5.5). At normal weaning time both the EW and NW were heavier than VEW heifers. Weights at the end of the backgrounding period in the following May were similar for EW and NW, however, VEW weighed less, although all treatments had similar weight gain from the time of NW to end of the backgrounding period. Heifer development costs were different ($P<0.05$) among all treatments. Feed cost was greatest for the VEW, followed by the EW and least for the NW heifers. However, at the end of the backgrounding period net income was greatest ($P<0.05$) for VEW, intermediate for EW and least for NW heifers (Table 5.5).

Table 5.5 Heifer backgrounding costs including, interest, depreciation, expenses of livestock, feed, and equipment for VEW, EW and NW treatments averaged over the three-year period of the study.

	Treatment[1]			
Item	VEW	EW	NW	SEM
Weight at very early weaning time, kg	117	117	117	
Weight at actual weaning, kg	117	195	241	
Market value at weaning, $/45 kg[2]	$150	$130	$123	
Value at weaning	$390.00	$563.33	$658.73	
Weight at start of backgrounding; 192 d, kg	211	234	241	
Sale wt, kg	317	345	343	
Heifer ADG, kg/d	0.6	0.6	0.6	
Market value at sale, $/45 kg	$113	$113	$113	
Gross sale receipts	$796.02[a]	$866.33[b]	$861.31[b]	6.26
Costs associated with backgrounding				
Post weaning pasture & supplements[3]	$57.83	$37.17	-	
Winter feed[4]	$103.42	$103.42	$103.42	
Yardage[5]	$77.60	$77.60	$77.60	
Bedding	$15.00	$15.00	$15.00	
Veterinary	$10.00	$10.00	$10.00	
Total operating interest[6]	$26.66	$28.29	$24.10	
Total operating costs	$290.51[c]	$271.48[b]	$230.12[a]	5.56
Net revenue / heifer	$115.51[c]	$31.52[b]	-$27.54[a]	7.75

[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned

[2] Market price of heifers at the point of weaning (72 d, 132d 192d); Canfax 2004

[3] Grazing cost based on calf AU equivalent and AUM priced at $23.50

[4] Based on hay at $.073/kg, barley at $.096/kg, protein supplement at $.239/kg, salt and mineral at $.738/kg

[5] Yardage based at $0.40 / day

[6] 6% annual interest rate

[a,b,c] Numbers within a row with differing letters differ *($P<0.05$)*

5.3.4 Overall enterprise analysis

The enterprise analysis that evaluated calf value at weaning, yearly cow costs per cow, and realized net revenue or loss from the marketing of finished steers and backgrounded heifers is shown in Table 5.6. The system analysis indicated that EWP ($14.22±5.65) generated the greatest net revenue per cow, followed by the EWF and NW (-$16.95 and -$23.29±5.65), followed then by VEWP (-$30.84 ± 5.65) and least profitable was VEWF (-$64.13±5.65).

Table 5.6 Net revenue or loss to the cow/calf enterprise from retained ownership of heifers and steers.

	Treatment[1]					
	VEWP	VEWF	EWP	EWF	NW	SEM
Calf market value at weaning per head[2]	$412.08	$412.08	$608.24	$608.24	$719.67	
Cow costs per head	($623.72)	($623.72)	($677.35)	($677.35)	($746.32)	
Net return from sale of backgrounded heifers and finished steers[3]	$180.08	$147.51	$83.33	$52.16	$3.36	
Net revenue or loss per cow	($30.84)[b]	($64.13)[a]	$14.22[d]	($16.95)[c]	($23.29)[bc]	5.65

[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normally Weaned steers

[2] Combined average market value of steers and heifer at the actual time of weaning; Canfax 2004

[3] Net revenue = sale revenue from steer minus feedlot cost and sale revenue from heifer minus backgrounding cost, divided by two

[a,b,c,d] Numbers within a row with differing letters differ significantly ($P<0.05$)

The enterprise analysis which evaluated the calf value at 192 days of age and took into account the backgrounding and yearly cow costs is shown in Table 5.7. This analysis indicated that EWP (-$15.93±5.47) and NW (-$26.65±5.47) generated the net revenue, followed by the EWF (-$57.54±5.47) and VEWP (-$79 78 ± 5.47) and least profitable was VEWF (-$159.37±5.47) if the calves were sold after the final (NW = 192 d) weaning treatment.

Table 5.7 Net revenue or loss to the cow/calf enterprise from the sale of backgrounded and weaned calves at the time of normal weaning (192 d).

	Treatment[1]					
	VEWP	VEWF	EWP	EWF	NW	SEM
Annual cow costs / head	($623.72)	($623.72)	($677.35)	($677.35)	($746.32)	
Average weight at weaning, kg[2]	220	235	227	235	255	
Price received for calves at weaning, $/45 kg[3]	$132	$130	$130	$130	$127	
Calf market value at weaning / head	$645.33	$678.88	$655.78	$678.88	$719.67	
Backgrounding expenditure[4]	($58.17)	($104.21)	($37.50)	($56.01)	-	
Net revenue at weaning / head	($79.78)[b]	($159.37)[a]	($15.93)[d]	($57.54)[c]	($26.65)[d]	5.47

[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normally Weaned steers

[2] Combined average of weight of heifers and steers at 192 d

[3] Combined average market value of steers and heifer at 192 d; Canfax 2004

[4] Average backgrounding costs between heifers and steers from weaning to 192 d of age.

[a,b,c,d] Numbers within a row with differing letters differ significantly ($P<0.05$)

5.4 Breakeven sensitivity analysis

5.4.1 Finishing enterprise

Breakeven sale values for the production of weaned and finished steers are summarized in Table 5.8. The weaned breakeven price to cover annual cow production costs was greatest for VEWP and VEWF steers followed by EWP and VEWF and lowest for NW treatments. The NW breakeven price, which factored in cow production costs and backgrounding cost of the steers to 192 d varied less across treatments. The NW, EWF and EWP had similar breakevens, while VEWP and VEWF had the highest. Finished steer economics, which evaluated the breakeven finished price based on the opportunity cost of the weaned steer at the time of weaning and the finishing costs, indicated that VEWP and VEWF had the lowest breakevens followed by EWP and EWF, with the NW having the greatest breakeven values.

Evaluation of the finished steers based upon a financial breakeven which used a breakeven price based upon the cost of production for a weaned steer plus the finishing costs indicated that EWP had the lowest, followed by NW, VEWP, EWF, and VEWF had the highest breakeven.

Table 5.8 Breakeven sale values ($/45kg) for production of weaned and finished steers.

	Treatments[1]					
Item	VEWP	VEWF	EWP	EWF	NW	SEM
Breakeven for $/45 kg						
Weaned breakeven[2]	\$222.75^{c}	\$222.75^{c}	\$145.84^{b}	\$145.84^{b}	\$124.38^{a}	7.10
NW breakeven[3]	\$134.06^{b}	\$135.05^{b}	\$127.71^{ab}	\$126.30^{a}	\$124.38^{a}	3.95
Steer Feedlot Enterprise						
Finished steer – economic[4]	\$78.51^{a}	\$79.42^{a}	\$83.17^{b}	\$88.32^{c}	\$91.30^{c}	2.48
Finished steer – financial[5]	\$88.68^{b}	\$94.14^{c}	\$84.97^{a}	\$90.07^{bc}	\$88.18^{ab}	2.07

[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF = Early Weaned Feedlot steers; NW = Normally Weaned steers

[2] ((Cow costs to produce weaned steer calf/ average weaning weight steer calf) x 45)

[3] ((Cow costs to produce weaned steer calf + backgrounding costs to 192 days)/ 192 d weight of the steer) x 45

[4] Finished steer-economic cost = [(Total costs for finished steer plus the feeder calf valued at its opportunity cost)/estimated final weight] × 45.

[5] Finished steer-financial cost = [(Total costs for finished steer plus the feeder calf valued at its production cost)/ final weight] × 45. The feeder calf valued at its production cost

[a,b,c] Numbers within a row with differing letters differ significantly ($P < 0.05$)

5.4.2 Heifer replacement enterprise

Breakeven sale values for production of weaned and backgrounded heifers are summarized in Table 5.9. As with the steers, the weaned breakeven value to cover annual cow production costs were greatest for VEW heifers followed by EW and least for NW treatments.

The NW weaned breakeven indicated EW and NW treatments had similar values and VEW heifers had significantly ($P<0.05$) higher breakeven values. After backgrounding the breakeven based upon the opportunity cost of the weaned heifer and the cost of backgrounding indicated that VEW had the lowest breakevens followed by EW and NW having the greatest.

Analysis on a financial basis, which evaluated the backgrounded price based upon the cost of production for the weaned heifer and the actual backgrounding costs indicated that EW had the lowest, followed by NW and VEW having the greatest breakeven to cover both heifer production and backgrounding costs.

Table 5.9 Breakeven sale values ($/45 kg) for production of weaned and backgrounded heifers.

	Treatment[1]			
Item	VEW	EW	NW	SEM
Breakeven for $/45 kg				
Weaned heifer[2]	\$239.89^{c}	\$156.31^{b}	\$139.35^{a}	7.43
NW breakeven[3]	\$145.35^{b}	\$137.40^{a}	\$139.35^{a}	3.35
Heifer Replacement Enterprise				
Backgrounded heifer - economic[4]	\$96.60^{a}	\$108.89^{b}	\$116.61^{c}	3.18
Backgrounded heifer – financial[5]	\$129.78^{b}	\$123.76^{a}	\$128.10^{ab}	1.72

[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned

[2] ((Cow costs to produce weaned calf/ average weaning weight heifer calf) x 45) at the time of treatment weaning

[3] [((Cow costs to produce weaned heifer calf + backgrounding costs to 192 days)/ 192 d weight of the heifers) x 45] and calculated at the time of NW

[4] Backgrounded heifer - economic cost = [(Total costs for backgrounding heifer plus the heifer calf valued at the opportunity cost)/estimated final weight] × 45.

[5] Backgrounded heifer - financial cost = [(Total costs for backgrounded heifer plus the heifer calf valued at its production cost)/final weight] ×45. The heifer calf valued at its production cost is the cow costs to produce the weaned calf.

[a,b,c] Numbers within a row with differing superscripts differ ($P < 0.05$).

5.5 Discussion

The results of this study indicate that altering weaning age will affect yearly cow/calf production costs. The effect is primarily through expenses related to pasture, winter feed costs and cow depreciation. As discussed in Chapter 3, VEW and EW treatments resulted in cows that had greater BW and BCS gains than cows that were NW. Because the nutrient requirements for lactation of VEW and EW cows had been removed earlier than for the NW cows, these cows could partition more consumed nutrients to BW and BCS gain beginning in July and September compared to November for NW cows. Along with decreases in nutrient requirements, there is a predicted decrease in the total dry matter intake of the cows on pasture. The earlier the cow/calf pairs were weaned the longer the pasture would last thereby stretching the available grazing resource. These reductions in forage demand resulted in a reduction in annual grazing costs to the specific treatment.

As discussed previously, part of the winter feeding experiment was compromised by weather anomalies and winter feeding design. As a result, winter feeding costs were calculated using formulas presented by Koberstein et al. (2001) and the intended winter feed ration for the treatments. This resulted in decreased winter feed costs for VEW and EW compared to the NW treatment. The results of decreased winter feed costs are in agreement with previous work by Myers et al. (1999b) and Story et al. (2000) who also investigated the influence of BW and BCS, on winter feed requirements for wintering beef cows.

The final difference in yearly cow cost between treatments was cow depreciation or culling expense. Over the three-year period there was a tendency, especially after the first year of the experiment, for a lower replacement rate in the VEW treatment compared to the EW and NW treatments. Many researchers (Lusby et al. 1981 and Whittier 1995) have concluded that weaning can have significant effects on cow conception rates if BCS is below 2.5 at calving (1-5 scale). However, if BCS is above this threshold, age of the animal will have a greater influence on conception rates. Although the cows in this experiment were not first calf heifers nor did the BCS fall below 2.5, the results of this experiment are in agreement with data reported by Arthington and Kalmbacher (2003) suggesting that early weaning can reduce cow replacement and culling rates.

Net income for steers in the feedlot enterprise (Table 5.4) favoured the VEWP followed by VEWF and EWP then by EWF and least by NW steers, when purchased at the time of weaning treatment. Economic factors that affected the outcome were primarily driven by the value of the steers at weaning, backgrounding/finishing costs and gross income from the finished steers. The gross income from the finished steer will be a function of the value of the calf at weaning, as well as the time of the year and weight they are sold at. As an example, VEWP and VEWF steers at weaning were lighter and, on a per unit weight basis, priced higher than the EWP, EWF and NW steers; however, because VEWP and VEWF steers weighed less at weaning, this resulted in a lower purchase-in cost to the feedlot. At slaughter, all treatments were priced equally and finished weight differences were marginal among treatments, which resulted in the greater gross income for VEWP, and VEWF. These results are in agreement with research from Story et al. (2000) who also concluded that the purchase-in costs and weights had a significant impact on feedlot profitability. However, Story et al. (2000) concluded that normal weaning (205 d) and/or late weaning (270 d) were more profitable than early weaning (150 d) to the cow/calf enterprise. The disadvantage of the early weaned calves in that experiment was related to decreased carcass weights and increased discounts due to poor yield grades. In this experiment a more aggressive implant program was used and there were only minor differences in carcass weights, with no carcass discounts against any treatments.

Additional differences in gross income from finished steers within weaning treatment can be explained by the differences in yardage cost associated with the backgrounding phase prior to the steers being placed onto the finishing ration. This explains why EWF was not as profitable at EWP and NW treatments even though weight gains were similar among treatments during this time period.

Heifer backgrounding costs were greater for the VEW heifers than for the EW and NW heifers. These differences in costs were primarily due to the greater amounts of supplemental feed required the earlier the heifers were weaned. Although the VEW heifers had the highest backgrounding costs, when analyzed on a net income basis, VEW heifers were the most profitable, followed by EW heifers and the least profitable being the NW heifers. The economic factors that affected the outcome were the value of the heifers at weaning, backgrounding costs and gross income from the backgrounded heifers. As with the steer treatments, VEW heifers were lighter and, on a per unit weight basis, were priced higher than the EW and NW heifers; however, because VEW heifers weighed less at weaning, this resulted in a lower purchase cost to the backgrounding phase. At the end of backgrounding, all treatments were priced equally and although VEW heifers weighed less than EW and NW heifers, their net returns were greater.

Evaluated as an entire system, in which ownership of steer calves were retained through to slaughter and replacement heifers were backgrounded and then sold at the end of May, the combination of EW and pasture backgrounding steers and heifers until normal weaning resulted in the greatest net revenue per cow compared to VEW and NW

(Table 5.6). This is in agreement with research by Knabel et al. (1989) that indicated a return of $112.10 more for early-weaned cow/calf pairs than for normal weaned cow/calf pairs. However, this research contradicts work by Allender et al. (1986) and Story et al. (2000) that indicated a greater net return to normal weaned cow/calf pairs than for early-weaned cow/calf pairs. These contradictions may have occurred due to the market prices used in the analysis. Differences can be generated if market prices used are the ones that occurred during the year the research was conducted or if a ten year average price is used in the analysis. Another factor with major implications on the net return of a weaning system is winter feed costs. Early weaned cows had decreased grazing costs and at the same time had the opportunity to gain in BC and BW. These gains in BC and BW could then be used to reduce winter feeding expenses. Conversely normally weaned cows had increased grazing costs and coupled with lower BCS and BW at the end of fall grazing period, winter feed costs increased to make up for the differences in BC and BW as compared to VEW and EW cows.

The revenue generated from selling backgrounded and weaned calves at 192 d was insufficient in covering annual cow production and calf backgrounding expenses. Pasture backgrounding systems had lower costs compared to feedlot backgrounding systems, however calves backgrounded under a feedlot backgrounding system had better gains than those under a pasture backgrounding system. The most influential variables affecting the breakeven values were yardage and feed costs, coupled with variations in animal performance under the different backgrounding systems.

Very early weaning, which significantly reduced grazing costs and increased cow BC and BW over early and normal weaning, did not generate enough gross calf value at the time of weaning to offset the annual costs of the cow. However, during times of severe drought, which would limit grazing and feeding resources, the economic stimulus to very early weaning may have greater economic potential. In this experiment there were no limitations on pasture resources and feed was relatively inexpensive and so the economic incentive to early weaning would be less. Adams et al. (1994) reached a similar conclusion. Story et al. (2000) found limited reductions of annual cow production cost by early weaning, this coupled with reduced carcass weight and carcass discounts was the reason their experiment favoured normal and/or late weaning.

The final major factor that had a significant influence on the return to assets was the system by which the early weaned calf was managed till normal weaning would have taken place. In this experiment yardage was calculated at $0.40/hd/day; over a period of 120 days there would be an additional expense of $48.00/calf if they were backgrounded in a feedlot as compared to backgrounded on pasture. Arthington and Kalmbacher (2003) suggested a way to increase the economic competitiveness of an early weaning system would be through backgrounding early weaned calves on highly managed improved pastures. Results from Chapter 3 indicated that aside from additional BCS and BW increase there were no biological advantages of VEW cows compared to the EW. The results also showed that once calves reached 132 days of age the pasture backgrounded calves performed almost as well as the calves that were still nursing. A way to overcome the issue of yardage expenses would simply be to delay weaning until the calves were more than 132 days and then background them on the best possible pasture with access to a high energy creep feed.

Findings from this study show that the majority of the annual cow costs are incurred by the time the calf is 72 d of age. However, the very early-weaned calf does not weigh as much at weaning as the EW and NW calf, and even though price per unit of weight is greater for the lighter-weight calf, there is not enough total revenue generated to offset the cow costs. Although the EW calves did not weigh as much as the NW treatment, the greater price per unit of weight, combined with a decrease in annual cow costs of production resulted in the most profitable case. This implies that the calf should only be weaned very early and sold at weaning if the annual cow cost rose dramatically due to e.g. drought-induced circumstances, severely limited grazing resources and or severe reductions in winter feed supplies. Under these circumstances it could also be argued that conception rates in younger cows may be compromised and so very early weaning may be an opportunity to limit the number of open cows. The VEWP steers generated the most revenue in the feedlot phase, but as a system, it still was not sufficient to offset the loss of revenue that occurred at weaning. As a management system, the profit potential for the NW system was influenced by cow costs, primarily through pasture and winter feed and the price received for the finished steer. The NW system ranked behind the EW system in this study for the three-year period, even though the NW steer calves weighed more at weaning and slaughter and generated more revenue than the VEW and EW treatments. A similar outcome is observed when breakevens for the finished steers are calculated on an economical basis.

Age of the calf at weaning resulted in shifting costs from one enterprise to another. For example, weaning calves at 132 d of age shifts costs from the cow herd to the backgrounding and feedlot enterprises. Profit potential of each weaning system is not only affected by feed costs, but also time of year when calves are weaned and moved into the feedlot / backgrounding lot and when the steers and heifers are marketed.

In this study we reject the null hypothesis – and conclude that after using enterprise budget and breakeven analysis to economically evaluate the biological data from Chapter 3, there were economic differences among very early wean (VEW: 72d), early weaning (EW; 132d) and normal weaning (NW; 192d) treatments.

5.6 Implications

What this study emphasizes is that before a decision is made on changing the weaning date it is important to know the costs of production for the cow/calf operation. Weaning affects both the production efficiency of the cow and that of the calf and this study showed it altered profitability by shifting costs from one enterprise to the next. It is feasible that a low cost backgrounding system using high quality pastures and energy supplementation could maintain acceptable calf gains for very early weaned calves. However, it is likely that very early weaned calves would perform better if managed in a confinement feeding system where their nutrition could be optimized. Adoption of a strategy using very early weaning could potentially give the most economical benefit during periods of severe drought, like 2002, where forage resources are typically restricted and feed very expensive. During drought extra body condition on the cows would also have a higher value than when there is a surplus of feed.

During normal years, delaying weaning by another 60 to 130 d, would result in calves that perform as well as normal weaned calves but would require less management than very early weaned calves. Backgrounding calves on pasture until the time of normal weaning would work well and net income for these calves may be similar if the yardage expense were eliminated for this time period.

Early weaning would still help improve cow BW and BCS compared to normal weaning. It would reduce the grazing pressure on the forage resource in the fall by at least 30% and if crop residues were available, allow their use with no detrimental effects to cow BC or BW. In the winter, the extra body condition could be used to reduce winter feed expenses.

To capture the full potential of a very early or early weaning management plan, retained ownership is essential. Even though lighter calves are often valued greater than heavier calves their reduced weights reduce the total gross dollars generated if the calves were sold at weaning. Depending upon the age, weight and sex of the calf there are also times where there can be reduced live weight gains of the calf. If calves are retained after weaning many of the negative aspects relating to slowed growth rates and reduced weights would be overcome by compensatory gain. Biological type of the calf and the cow (body size, the propensity to fatten, milking potential, and growth rate) would also be factors that need to be taken into consideration in designing the weaning, backgrounding and/or finishing program. Most importantly, understanding the costs of production of a cow calf operation and how weaning as a management tool shifts costs from one livestock enterprise to another is crucial, if weaning is the approach taken to reduce costs of production.

As previously discussed feed costs are by far the largest expense within a cow/calf operation. Feed shortages and/or drought can have a big impact on feed values. Conversely feed surpluses can have the opposite effect. The economic evaluation of this chapter was done using average feed values over a four year period. In the next Chapter a similar economic evaluation of the cow/calf production system will be done using feed values based upon a Low Feed Cost (LFC) and High Feed Cost (HFC) scenario.

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CHAPTER 6

SIMULATION OF THE EFFECTS OF LOW AND HIGH FEED COSTS ON THE ECONOMIC IMPLICATIONS OF EARLY WEANING

6.1 Introduction

As discussed in the previous chapters the largest expense in maintaining a cow herd is the feed consumed, either in the form of winter feed or summer grazing. This expense will vary from region to region, depending on climate and resources available.

Drought and weather induced feed shortages and surpluses can have a large effect on the net return to cow calf enterprises. Drought primarily affects cow calf returns by increasing the need for increased stored feeds and pasture, along with their value. On the revenue side drought can negatively affect the value of weaned calves by increasing post weaning backgrounding and finishing costs due to an associated rise in feed costs.

The effects of drought were confirmed through work by Dierson and Taylor (2003) who analyzed the economic impact of the 2002 drought on South Dakota cow calf producers. They found that the severe moisture shortfall of 2002 decreased net returns to South Dakota cow calf producers by $US 238 million through increased pasture rental and winter feeding expenses. Expressed on a per head basis pasture costs increased by $US 73 and winter feed costs increased by $US 53/cow wintered. The winter feeding period for South Dakota producers is usually 90 days. The authors concluded that if the winter feeding period were extended to 180 days because of severe pasture limitations, the additional cost of winter feed would have been over $US 100 /cow wintered. The dollar impact of the drought on the value of weaned calves was estimated at $US 10/cwt.

Opposite to drought, increased levels of precipitation can cause surpluses of winter feed and summer pasture. These surplus supplies of feed and fodder decrease the value of these resources which increases the value of weaned calves because of the opportunity to value-add to these feeds by feeding cattle (Julien and Tess, 2002).

Manipulating the time of weaning can significantly alter the economic returns for a cow calf production system during periods of normal feed and pasture production. The objective of this chapter is to evaluate the effects of the weaning treatments described in the previous chapters for a year with below average feed production (High Feed Cost; HFC) and for one with above average feed production (Low Feed Cost; LFC)

6.2 Material and Methods

From the biological results presented in Chapter 3, an enterprise budget employing excel spreadsheets was used to determine the economic results of a HFC and LFC year on the profitability of each weaning treatment. Using the four-year average feed cost reported by AFSC (2004) for the time period 1998 – 2001, prices were either increased by 30% to represent HFC or decreased 30% to represent LFC (Table 6.1). Labor, overhead and operating costs associated with feeding were determined from data reported by Kaliel et al. (2004) in the Benchmarks for Alberta Grazing costs and AUM values were calculated using data reported by AFSC (2004). AUM values were either increased by 30% to represent a HFC or decreased to represent a LFC (Table 6.1). Grazing costs were calculated based on cow lactational status and AUM value. Cull cow and calf values were also adjusted over the two scenarios to reflect the increase or decrease in marketings relating to feed and pasture availability. For the simulation, all biological inputs for animal performance, morbidity and mortality stayed identical to those reported in Chapter 3.

Table 6.1 Input prices used in the simulations of LFC and HFC years

	Unit	Low Feed Cost	Normal Feed Cost	High Feed Cost
Feed				
1st cut grass/alfalfa hay	$/ 1000 kg	$51.10	$73.00	$95.00
second cut mixed hay	$/ 1000 kg	$60.00	$85.00	$110.50
Barley grain	$/ 1000 kg	$67.20	$96.00	$125.00
Oat grain	$/ 1000 kg	$55.00	$78.58	$102.14
Calf Starter	$/ 1000 kg	$182.00	$260.00	$338.00
Summer pasture	$/AUM	$16.50	$23.50	$30.55
Livestock				
Steers				
125 – 174 kg	$ / 45 kg	$168.00	$158.00	$148.00
175 – 224 kg	$ / 45 kg	$148.00	$138.00	$128.00
225 – 274 kg	$ / 45 kg	$140.00	$130.00	$120.00
275 – 349 kg	$ / 45 kg	$132.00	$122.00	$112.00
350 - 424 kg	$ / 45 kg	$124.00	$114.00	$104.00
Slaughter wt.	$ / 45 kg	$94.00	$94.00	$94.00
Heifers				
125 – 174 kg	$ / 45 kg	$160.00	$150.00	$140.00
175 – 224 kg	$ / 45 kg	$140.00	$130.00	$120.00
225 – 274 kg	$ / 45 kg	$132.00	$122.00	$112.00
275 – 349 kg	$ / 45 kg	$117.00	$112.00	$108.00
350 - 424 kg	$ / 45 kg	$110.00	$105.00	$100.00
Cull Cow - Value	$ / 45 kg	$55.00	$45.00	$40.00

6.2.1 System evaluation

Inputs into the enterprise budget analysis were animal performance, feed requirements and prices. The net revenue or loss per cow for each weaning treatment was evaluated based on the cost/return data from the cow, heifer backgrounding, and steer-feedlot enterprises. Income was generated from the sale of finished steers and backgrounded heifers. The assigned calf value for each weaning management system was based on the weight of the calves at each weaning period and the value of steers and heifers at the point of weaning. Prices were expressed on a $value / 45 kg increment. Feed requirements did not differ across simulation scenario but were adjusted in value to reflect the HFC and LFC year (Table 6.1). Labor for checking cattle while they were grazing was included as part of the AUM grazing cost, whereas feedlot labor was considered part of the yardage charge. For the cows a flat labor and custom work expense was assigned across all three treatments. Slaughter values were based upon actual live slaughter weights and the four-year average (1998-2001) price for the May – June time period (Canfax 2004).

6.2.2 System and scenario evaluation

The analysis first evaluated the yearly costs per cow. This was determined by dividing the yearly cow management and feed costs by the proportion of live calves weaned per cow calved. From the yearly cow costs the net profit or loss from the sale of weaned calves back to the cow enterprise was determined. As the heifers and steers were backgrounded or fed through their respective post weaning treatments the realized net return of each weaning treatment was determined. Then the economic analysis compiled all the returns of the respective backgrounding and or finishing systems to determine the overall returns against the yearly cow production costs. The last step was a breakeven analysis to determine the returns needed at weaning, backgrounding and finishing to make the enterprise cover the cost of production.

6.3 Results and discussion

6.3.1 Cow/Calf enterprise

Annual winter feed and grazing expenses for cows in the simulation ranged from as low as $189.19 for VEW cows in a LFC year to as high as $468.48 for NW cows in a HFC year (Table 6.2). Under a LFC scenario, pasture and winter feeding expenses would decrease, due to a larger supply of both. Conversely under a HFC, feed costs would increase because of reduced supplies of winter feed and increased demand. Pasture expenses would also increase through a number of factors: 1) a rented quarter would produce less AUMs 2) more rented land would be required or 3) greater demand for pasture and consequently a rise in its $ value / AUM.

Table 6.2 Annual cow/calf production cost for weaning treatments x feed costs.

	LOW FEED COSTS			HIGH FEED COSTS		
	VEW	EW	NW	VEW	EW	NW
Winter feed and bedding	$98.31	$111.42	$131.08	$182.57	$206.92	$243.44
Pasture	$90.88	$103.00	$121.18	$168.78	$191.28	$225.04
Total feed costs	$189.19	$214.42	$252.26	$351.35	$398.20	$468.48
Veterinary and medicine	$20.00	$20.00	$20.00	$20.00	$20.00	$20.00
Breeding fees/bull rental	$40.00	$40.00	$40.00	$40.00	$40.00	$40.00
Repairs - machine corrals and buildings	$35.00	$35.00	$35.00	$35.00	$35.00	$35.00
Utilities, fuel and miscellaneous expenses	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00
Custom work & labor	$166.72	$166.72	$166.72	$166.72	$166.72	$166.72
Total vet, breeding and yardage	$286.72	$286.72	$286.72	$286.72	$286.72	$286.72
Cow depreciation cost[2]	$55.50	$70.50	$76.50	$66.60	$84.60	$91.80
Calf weaning %	99%	99%	98%	99%	99%	98%
Annual cow costs / head[2]	$531.41	$571.64	$615.48	$704.67	$769.52	$847.00

[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned

[2] Cow depreciation was calculated using the difference between cow cull values and the values for bred replacements; Canfax (2004)

The variation in these expenses resulted in annual cow production costs ranging from as low as \$531.41/hd for VEW cows in a LFC year, to as high as \$847.00/hd for NW cows in a HFC year. Fixed costs for labor and interest on cows were included in these expenses. The variation in annual cow production costs strongly influenced the net return to the cow calf enterprise (Table 6.3). Under a LFC scenario net returns from the sale of weaned calves were least for VEW cows at -\$103.12 and most for NW cows at \$136.89; EW cows were intermediate with a net return of \$84.73. In a HFC year all weaning treatments yielded negative net returns from the sale of weaned calves. Similar to the LFC year, returns were the least for VEW cows, intermediate for EW and the greatest for the NW cows under a HFC scenario. Feed and pasture costs were negatively related in a linear fashion to the net returns of the cow enterprise from the sale of weaned calves (Figure 6.1).

Table 6.3 Annual cow costs and revenues for VEW, EW and NW weaning treatments under LFC and HFC scenarios.[1,2]

	LOW FEED COST			HIGH FEED COST		
	VEW	EW	NW	VEW	EW	NW
Annual cow costs / head[3]	\$531.41	\$571.64	\$615.48	\$704.67	\$769.52	\$847.00
Average weight at weaning, kg[4]	122	203	256	122	203	256
Value of calves at weaning, \$/45 kg[5]	\$163.00	\$145.50	\$137.00	\$144.00	\$125.50	\$119.00
Calf market value at weaning / head	\$428.29	\$656.37	\$779.37	\$390.40	\$566.14	\$671.28
Net return from sale of weaned calf	-\$103.12	\$84.73	\$136.89	-\$314.27	-\$203.38	-\$175.72

[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned

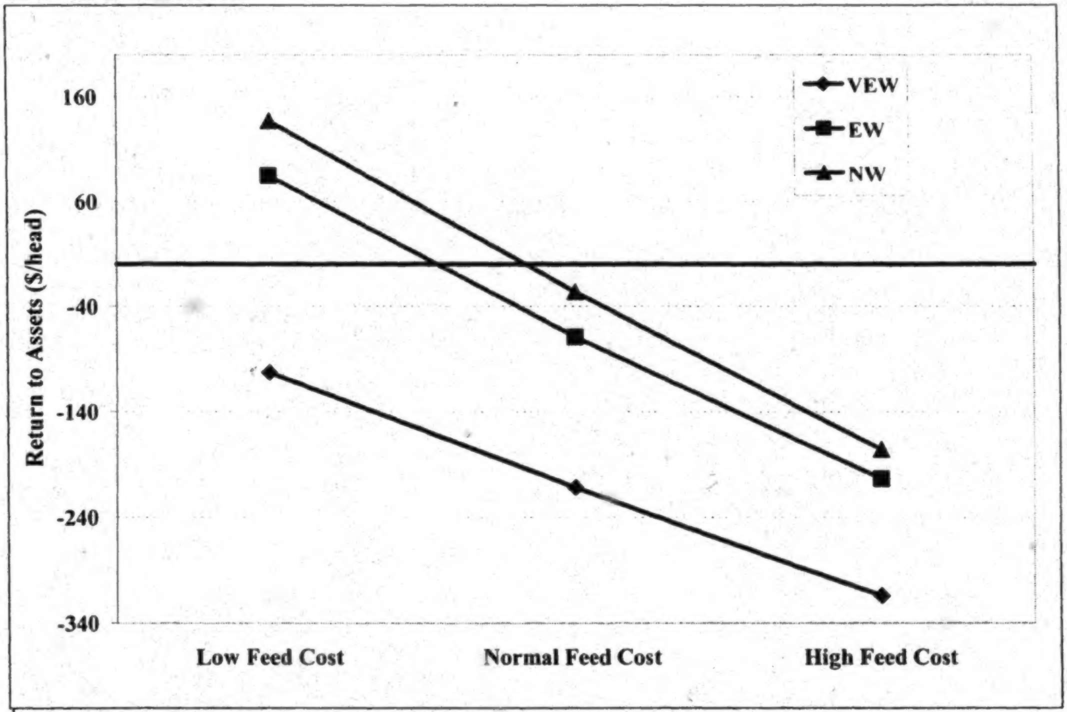
[2] LFC = Low Feed Cost; HFC = High Feed Cost

[3] Cow costs to produce weaned calf adjusted by the weaning ratio

[4] Average weights of steers and heifers at the time of weaning

[5] Average market prices of weaned steers and heifers

Figure 6.1 Return to assets from the sale of VEW, EW and NW calves under LFC and HFC scenarios.[1,2]



[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normal Weaned

[2] LFC = Low Feed Cost; HFC = High Feed Cost

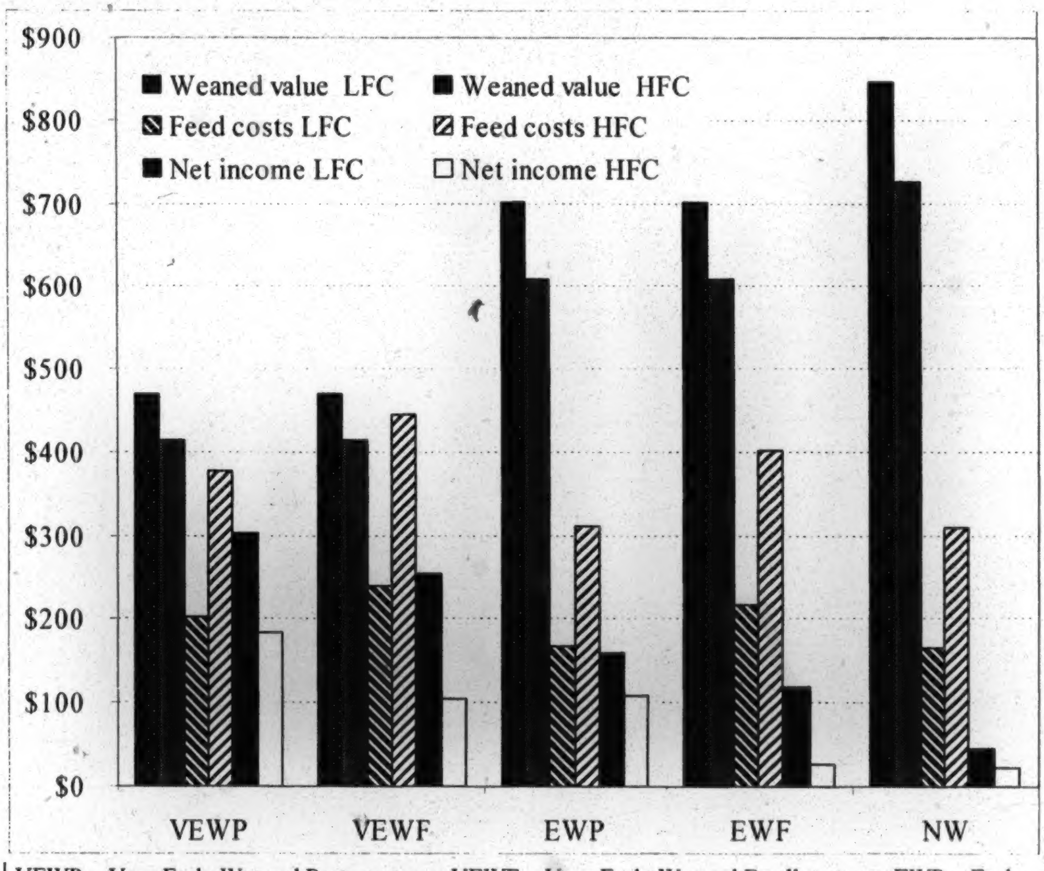
6.3.2 Finishing enterprise

In LFC and HFC years, weaned calf prices were adjusted using data reported by Dierson and Taylor (2003) to reflect the expected change in calf prices that would happen due to surpluses or shortages of feed (Table 6.1). Animal performance stayed constant across treatments for both simulations.

As would be expected, feeding expenses were the least for the LFC and greatest for the HFC scenario (Figure 62.) Under the LFC scenario, VEWF steers had the greatest feed expenses and NW steers had the least. After the returns from the sale of finished steers were added to the finishing and or backgrounding expenses, the most profitable weaning treatment was the VEWP steers with a net return of $304.02. The least profitable group of steers in a LFC year would be NW steers, with a net return of $45.73.

Although net returns were reduced for all treatments under the HFC scenario, they showed the same trend as the LFC scenario. In a high feed cost year VEWF steers would have the highest feed costs and NW steers would still have still the least; all other treatments were intermediate. VEWP steers were again the most profitable; least profitable were the NW steers, with all other treatments in between (Table 6.4; Figure 6.2).

Figure 6.2 Comparison of VEWP, VEWF, EWP, EWF and NW steer calf values, total feed costs and net revenues under LFC and HFC scenarios.[1,2]



[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normally Weaned steers

[2] LFC = Low Feed Cost; HFC = High Feed Cost

The main factors affecting the returns both under a LFC and HFC scenario were the amount and value of the feed, yardage required to get the steers to finish and value of the steers at weaning. Although feed was a large component of the expense of finishing the steers, the amount of feed stayed constant and so feed expense across treatments decreased/increased proportionally. Returns to all weaning treatments increased under the LFC scenario because the feed expense was a smaller proportion of the total production costs. Under a HFC scenario the opposite occurred.

Table 6.4 Steer finishing costs including interest, depreciation, expenses of livestock, feed, and equipment for LFC and HFC scenarios.[1]

	Low Feed Cost					High Feed Cost				
	VEWP	VEWF	EWP	EWF	NW	VEWP	VEWF	EWP	EWF	NW
Initial weight, kg	126	126	209	209	270	126	126	209	209	270
Market value at weaning, $/45 kg[2]	$168	$168	$151	$151	$141	$148	$148	$131	$131	$121
Gross weaned value	$470.40	$470.40	$701.31	$701.31	$846.00	$414.40	$414.40	$608.42	$608.42	$726.00
ADG during backgrounding period	0.87	1.1	0.9	1	-	0.87	1.1	0.9	1	-
Backgrounding period, d	123	123	61	61	0	123	123	61	61	0
Weight at the end of the backgrounding[3]	233	261	264	270	270	233	261	264	270	270
Final weight	537	554	562	577	572	537	554	562	577	572
Market value at finish, $/45 kg	$94	$94	$94	$94	$94	$94	$94	$94	$94	$94
Gross income from finished steer	$1,122	$1,157	$1,174	$1,205	$1,195	$1,122	$1,157	$1,174	$1,205	$1,195
Days on feed	178	175	177	175	176	178	175	177	175	176
Backgrounding costs										
Feed, pasture and supplements[3]	$40.95	$70.98	$26.48	$35.32	-	$760.05	$131.82	$49.18	$65.60	-
Yardage[4]	-	$49.20	-	$24.40	-	-	$49.20	-	$24.40	-
Costs associated with finishing										
Feed costs	$162.66	$168.69	$141.62	$181.00	$166.75	$302.08	$313.29	$263.00	$336.14	$309.67
Bedding	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00
Yardage	$71.20	$70.00	$70.80	$70.00	$70.40	$71.20	$70.00	$70.80	$70.00	$70.40
Vet and induction	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
Trucking	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00
Total operating interest[5]	$32.50	$33.74	$33.00	$34.19	$25.97	$32.50	$33.74	$33.00	$34.19	$25.97
Total operating costs	$347.31	$432.61	$311.90	$384.91	$303.12	$521.83	$638.05	$455.98	$570.33	$446.04
Net income / steer	$304.02	$254.23	$160.75	$119.07	$45.73	$185.50	$104.80	$109.55	$26.54	$22.80

[1] VEWP = Very Early Weaned Pasture; VEWF = Very Early Weaned Feedlot; EWP = Early Weaned Pasture; EWF= Early Weaned Feedlot; NW = Normally Weaned

[2] Market price of steers at the point of weaning (72 d, 132d or 192d); Canfax 2004

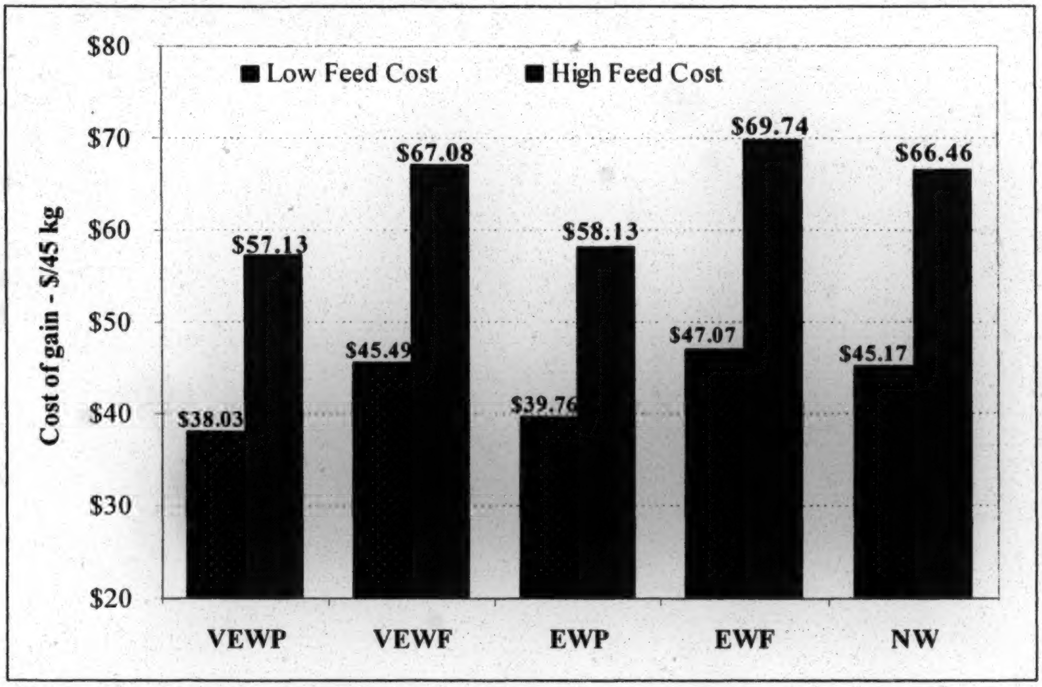
[3] Weights of steers at 192d

[4] Yardage charged at $0.40 / steer / day

[5] 6% annual interest rate

Yardage also affected total costs. In this simulation steers that were backgrounded in a feedlot setting were charged yardage at $0.40 /hd/day, whereas for steers that were backgrounded on pasture the yardage was considered part of the pasture AUM value. Thus, the differences in yardage values between pasture and feedlot backgrounded steers resulted in a $7-10/45 kg difference in the cost of gain. For example the combination of a HFC scenario coupled with the yardage cost of feedlot backgrounding is why there was little difference in the returns of EWF and NW steers, as opposed to a greater than $80/kg difference in returns between EWP and EWF steers.

Figure 6.3 Feedlot cost of gain for VEWP, VEWF, EWP, EWF and NW steers ($/45 kg) under LFC and HFC scenarios.[1,2]



[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normally Weaned steers

[2] LFC = Low Feed Cost; HFC = High Feed Cost

The last factor that could explain the differences in profitability between treatments was the value of steers at weaning. Even though the earlier weaned steers were valued higher on a per unit weight basis than later weaned calves, on a per head basis they were worth less than the later weaned steers because they were lighter. Then once the steers were finished the total value of the steers was almost identical across treatments. The opportunity value of calves at weaning resulted in a larger difference between VEW steers and EW and NW steers, and a larger difference between EW and NW steers.

6.3.3 Backgrounded heifer enterprise

Parallel to the finishing economic information of the steers, VEW heifers were the most profitable in a LFC simulation (Table 6.5). Even though VEW heifers had the greatest feed expense of the three weaning scenarios, their lower per head value as they entered the backgrounding phase resulted in making them the most profitable. Conversely, the NW heifers had the lowest feed costs of the three weaning treatments but the greatest opportunity value at weaning. This made them less profitable then the VEW and EW heifers.

Under the HFC simulation all treatments had reduced returns and profitability. The only profitable treatment was the VEW heifers. Returns for EW and NW heifers were negative after factoring in feed and yardage costs along with the weaning value of the heifers for the backgrounding period.

The reduced return under the HFC simulation was influenced by several factors. Unlike the steers, the value of the heifers at the end of the winter backgrounding would still be affected by high feed costs. An increase in the cost of gain for finishing under a HFC scenario would reduce the value of the heifers at the end of the backgrounding period. Conversely a decrease in feed costs under the LFC scenario would stimulate an increase in the value of the backgrounded heifers as they move to the finishing phase, which would occur after they were sold as feeders.

Table 6.5 Backgrounding expenses and receipts for VEW, EW and NW heifers under LFC and HFC scenarios.[1]

	Low Feed Cost			High Feed Cost		
	VEW	EW	NW	VEW	EW	NW
Weight at weaning, kg	117	195	241	117	195	241
Market value at weaning, $/45 kg[2]	$158	$140	$133	$140	$120	$113
Gross weaned receipts	$410.80	$606.67	$712.29	$364.00	$520.00	$605.18
Weight at start of winter backgrounding, kg[3]	211	234	241	211	234	241
Weight at the end of backgrounding, kg	317	345	343	317	345	343
Heifer ADG, kg/d	0.6	0.6	0.6	0.6	0.6	0.6
Market value at sale, $/45 kg	$118	$118	$118	$108	$108	$108
Gross sale receipts	$831.24	$904.67	$899.42	$760.80	$828.00	$823.20
Costs associated with backgrounding						
Post weaning pasture & supplements	$40.48	$26.02	-	$75.18	$48.32	-
Winter feed	$72.39	$72.39	$72.39	$134.45	$134.45	$134.45
Yardage[4]	$77.60	$77.60	$54.32	$77.60	$77.60	$77.60
Bedding	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00
Veterinary	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
Total operating interest[5]	$26.66	$28.29	$24.10	$26.66	$28.29	$24.10
Total operating costs	$242.14	$229.30	$175.81	$338.89	$313.66	$261.15
Net income / heifer	$178.31	$68.70	$11.32	$57.92	-$5.66	-$43.12

[1] VEW = Very Early Weaned heifers; EW = Early Weaned heifers; NW = Normally Weaned heifers

[2] Market price of heifers at the point of weaning (72 d, 132d 192d); Canfax 2004

[3] Weights of heifers at 192d

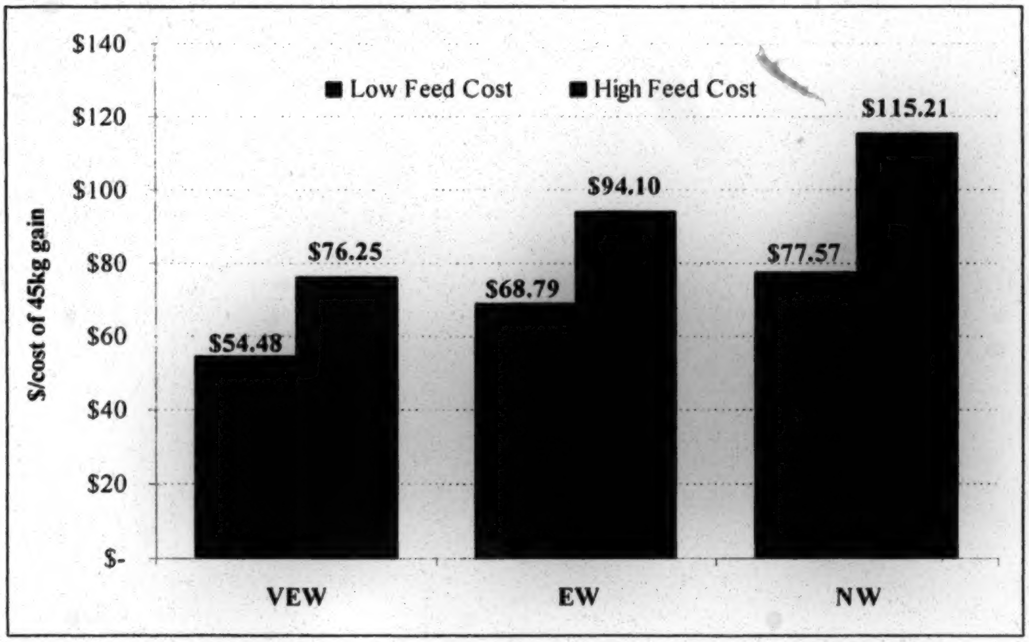
[4] Yardage charged at $0.40 / heifer / day

[5] 6% annual interest rate

Another explanation for the reduced returns under a HFC scenario was that heifers were gaining less than 0.75 kg/day. Yardage costs in this experiment stayed constant; however with a low rate of gain coupled with an increase in the cost of feed the results would be an increase in the cost of gain (Figure 6.4)

The result of the differences between the LFC and HFC simulation along with the yardage costs explain the differences in profitability for the backgrounded heifers. Similar results and patterns for backgrounded calf values have been documented by Kaliel et al.(2004).

Figure 6.4 Winter backgrounding costs of gain for VEW, EW and NW heifers ($/45 kg) under LFC and HFC scenarios.[1]



[1] VEW = Very Early Weaned heifers; EW = Early Weaned heifers; NW = Normally Weaned heifers

[2] LFC = Low Feed Cost; HFC = High Feed Cost

6.3.4 Overall enterprise analysis

The simulation of LFC and HFC years evaluated the calf at weaning, yearly cow costs, and realized net returns from the marketing of finished steers and backgrounded heifers (Table 6.6). Under the LFC scenario, by retaining ownership of the weaned calves through backgrounding and finishing, all weaning treatments showed a positive economic contribution to the cow calf operation. Variation among treatments from lowest to highest was $89.97; the VEWF treatment had the lowest returns and NW highest.

With a HFC scenario all weaning treatments had a negative return to the cow calf enterprise. The lowest returns were again to the VEWF treatment (-$213.69), followed by the EWF treatment (-$181.22). The EWP weaning treatment lost the least (-$139.71/cow). These results mirror the numbers documented by Dierson and Taylor (2003), who studied the economic implications of the 2002 drought on South Dakota cow calf producers.

Table 6.6 Net revenue or loss by various weaning, backgrounding, finishing treatments and winter feed costs under LFC and HFC simulation[1]

	Low Feed Cost					High Feed Cost				
	VEWP	VEWF	EWP	EWF	NW	VEWP	VEWF	EWP	EWF	NW
Calf market value at weaning per head[2]	$428.29	$428.29	$656.37	$656.37	$779.37	$390.40	$390.40	$566.14	$566.14	$671.28
Cow costs per head	-$531.41	-$531.41	-$571.64	-$571.64	-$615.45	-$704.67	-$704.67	-$769.52	-$769.52	-$847.00
Net return from sale of backgrounded heifers and finished steers[3]	$241.16	$216.27	$114.73	$93.88	$33.27	$121.71	$81.36	$51.95	$10.44	-$10.19
Net revenue or loss per cow	$138.04	$113.15	$199.46	$178.61	$197.19	-$192.56	-$232.91	-$151.43	-$192.94	-$185.91

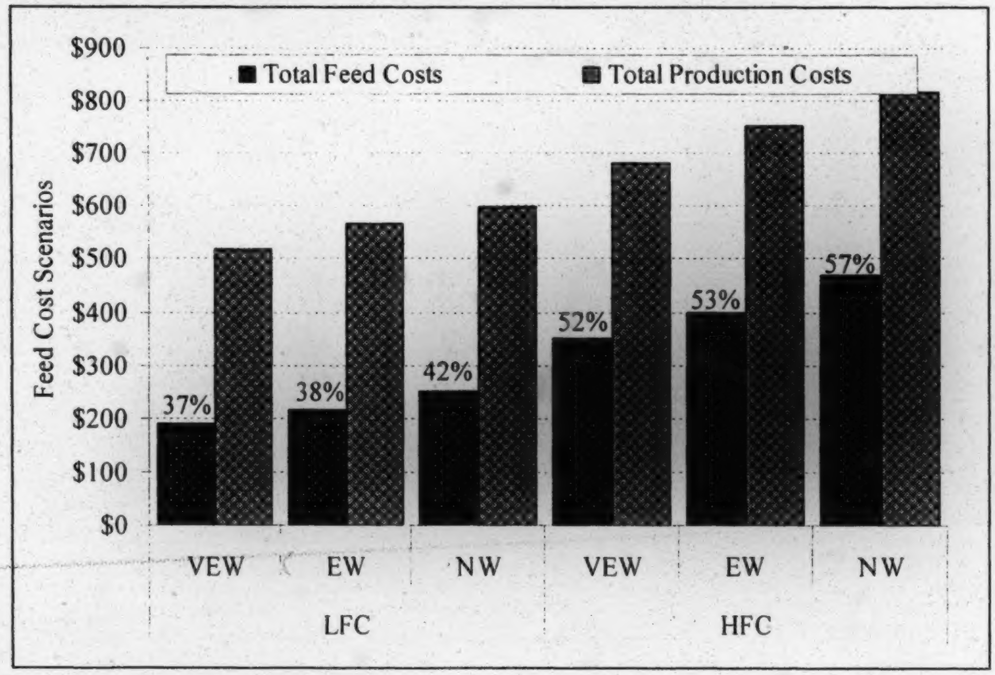
[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normally Weaned steers

[2] Combined average market value of steers and heifer at the actual time of weaning; Canfax 2004

[3] Net revenue = sale revenue from steer minus feedlot cost and sale revenue from heifer minus backgrounding cost, divided by two

Feed and pasture costs have been well documented as having a large impact on the profitability of cow/calf enterprises (Werth et al. 1991; Story et al. 2000; Kaliel et al. 2004). During LFC years the impact of reduced feed expenses, expanded grazing resources and a greater demand for cattle to eat the surplus feed; all contribute to a scenario where profitability to the cow/calf enterprise is almost guaranteed. Conversely, during HFC years decreased availability of grazing resources, lower cow body condition scores, longer days of feeding, more expensive feed and a reduced demand for cattle to feed make it more difficult to return a positive margin to the cow enterprise. All these factors were big contributors to the negative margins of cow/calf producers during and after the drought of 2002 (Kaliel, 2004). Figure 6.5 shows a comparison of the total feed costs in relation to the total annual cost under LFC and HFC scenarios.

Figure 6.5 Comparison of pasture/winter feed costs and total production costs for VEW, EW and NW treatments under LFC and HFC scenarios.[1,2]

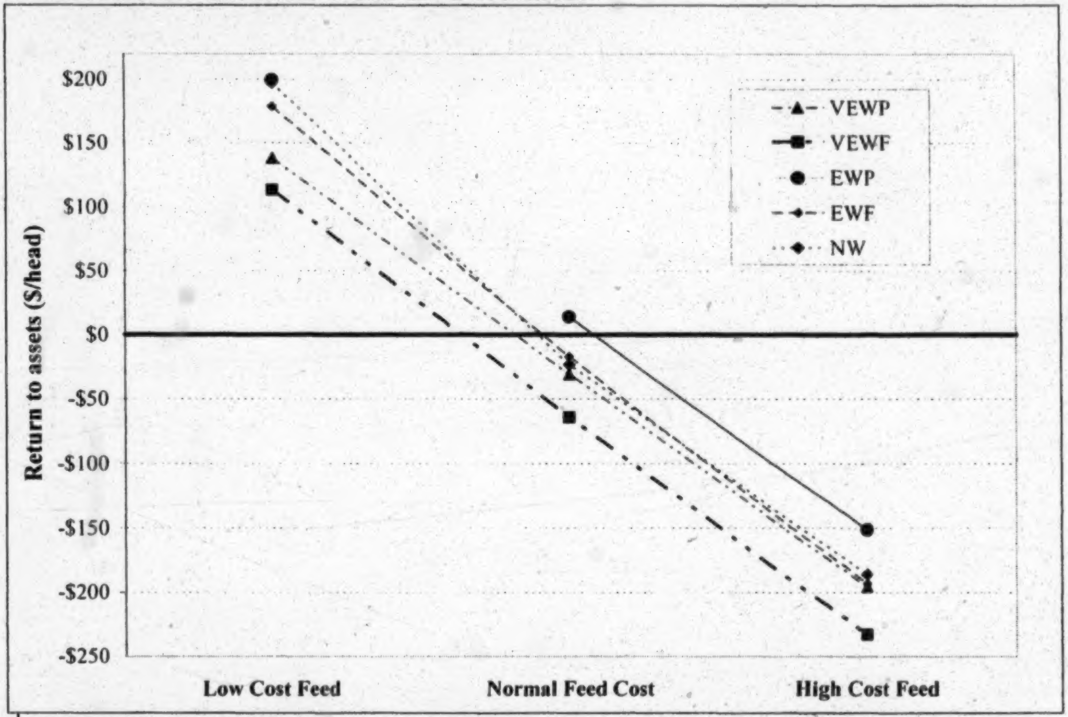


[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned

[2] LFC = Low Feed Cost; HFC = High Feed Cost

As discussed in Chapter 5 winter feed and pasture costs are major contributors to expenses within cow/calf enterprises and in the case of this simulation caused a negative linear effect on return to asset (Figure 6.6). As winter feed and pasture needs increase and/or increase in their value, return to assets decrease.

Figure 6.6 Return to assets from combinations of VEWP, VEWF, EWP, EWF and NW treatments under LFC and HFC scenarios.[1,2]



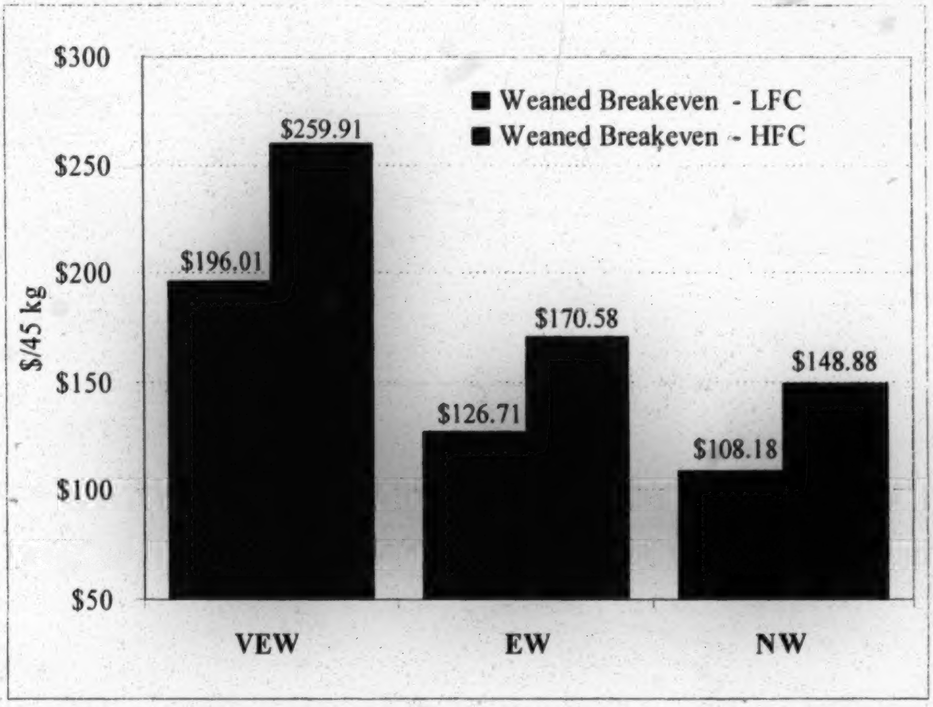
[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normally Weaned steers

[2] LFC = Low Feed Cost; HFC = High Feed Cost

6.3.5 Weaned calf breakeven

The weaned breakeven price needed to cover annual cow production costs was highest for the VEW treatments in both the LFC and HFC scenarios (Figure 6.7). The lowest weaned breakeven needed to cover annual cow production costs was for the NW treatments in both the LFC and HFC. The weaned breakevens for the EW were intermediate. The differences in breakevens between treatments could largely be explained by differences in cow production costs and differences in the weights of the calves at weaning. Even though VEW cows had lower annual production costs under both the LFC and HFC scenarios, the lighter weaning weight increased the breakeven value needed to cover the costs of production. Conversely, the NW treatments had higher production costs in both the LFC and HFC scenarios but their heavier weaning weight combined to offset these increased costs.

Figure 6.7 Breakeven sale prices ($/45 kg) for VEW, EW and NW weaned calves.[1,2]



[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned

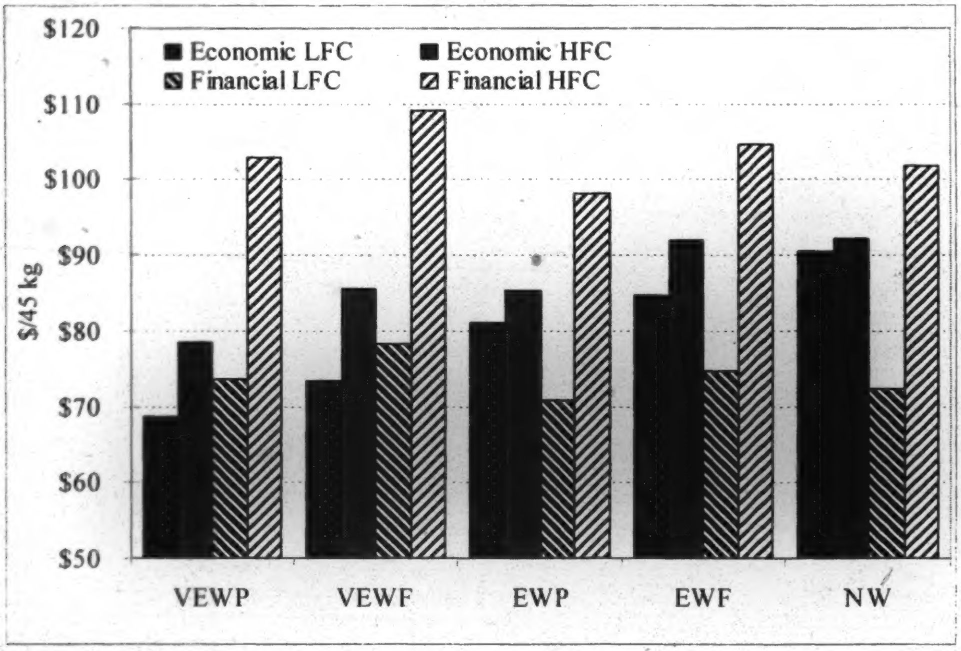
[2] LFC = Low Feed Cost; HFC = High Feed Cost

6.3.6 Finished steer breakeven

Breakevens for finished steers are illustrated in Figure 6.8. Finished steer economics, which evaluated the breakeven finished price based on the opportunity cost of the weaned steer at the time of weaning and the finishing costs, indicated that VEWP and VEWF had the lowest breakevens followed by EWP and EWF, with the NW having the greatest breakeven values under both the LFC and HFC scenario.

Evaluation of the finished steers based upon a financial breakeven, which used a breakeven price based upon the cost of production for a weaned steer and the finishing costs, indicated that EWP had the lowest, followed by NW, EWF, VEWP and VEWF had the highest breakeven in both the HFC and LFC scenarios. The differences between EWP and NW were marginal.

Figure 6.8 Breakeven sale prices ($/45 kg) for VEWP, VEWF, EWP, EWF and NW finished steers.[1,2]



[1] VEWP = Very Early Weaned Pasture steers; VEWF = Very Early Weaned Feedlot steers; EWP = Early Weaned Pasture steers; EWF= Early Weaned Feedlot steers; NW = Normally Weaned steers

[2] LFC = Low Feed Cost; HFC = High Feed Cost

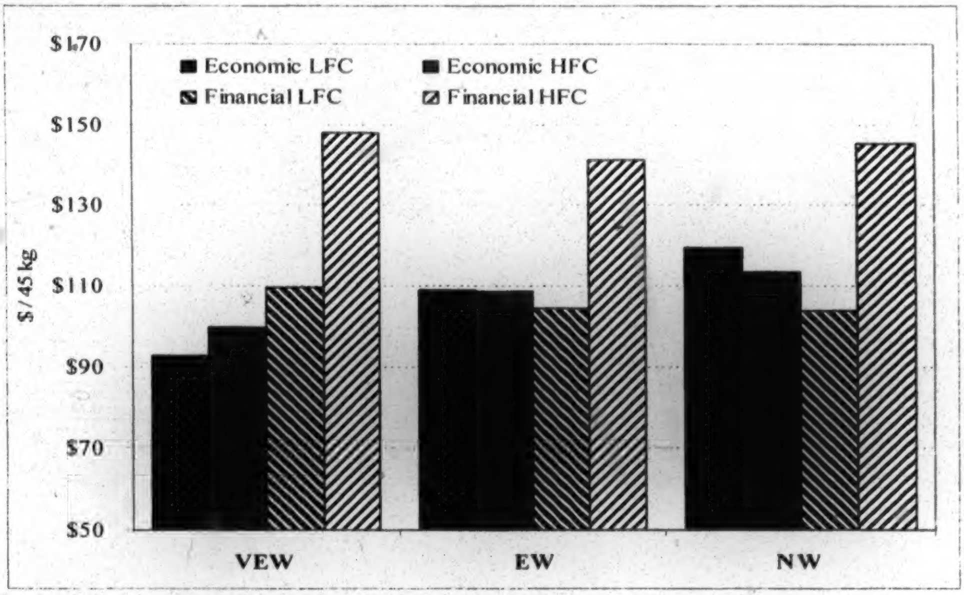
6.3.7 Backgrounded heifer breakeven

Breakevens for the backgrounded heifers are illustrated in Figure 6.9. Just like the steers, the economic backgrounding breakeven for heifers was based upon the opportunity cost of the weaned heifer and the cost of backgrounding. It indicated that VEW heifers had the lowest breakevens followed by EW and NW having the highest in both the LFC and HFC scenarios.

Analysis on a financial basis, which evaluated the backgrounding price based upon the cost of production for the weaned heifer and the actual backgrounding costs, indicated that all treatments had similar breakevens under both a LFC and HFC scenario. All treatments had increased breakeven values for HFC scenarios. The reasoning behind a limited difference in the financial breakeven value of the heifers was mostly related to the lower rates of gain over the backgrounding period.

The VEW heifers were the most profitable for the backgrounding enterprise because they were valued the lowest on a per head basis when they entered it. Conversely, on a return from the sale of weaned calves, VEW heifers returned the least to the cow/calf enterprise. On the other end of the scale NW calves returned the most at weaning to the cow calf enterprise but as a profit centre in the backgrounding phase they did the poorest. Combining the cost and returns of both the enterprises resulted in similar breakevens at the end of the backgrounding phase.

Figure 6.9 Breakeven sale prices ($/45 kg) for VEW, EW and NW backgrounded heifers.[1,2]



[1] VEW = Very Early Weaned; EW = Early Weaned; NW = Normally Weaned

[2] LFC = Low Feed Cost; HFC = High Feed Cost

6.4 Implications

Results from this simulation suggest that under Low feed cost and High feed cost scenarios there can be considerable shifting in the cost and returns to the cow/calf enterprise. During both simulations very early and early weaning reduced the cost of production for the cow/calf enterprise compared to normal weaning. However, when returns for weaned calves were added to the cow/calf production costs there was no economic advantage of very early and early weaning over normal weaning. The production costs that were reduced by altering the weaning age, were not reduced enough to offset the reduced revenues generated from the sale of the lighter weight calves. If weaning is to be used as a tool to manage costs, evaluation of the weaned breakeven values needed to cover costs of production for the cow/calf enterprise must be calculated, especially if calves are not retained beyond weaning.

Under a LFC scenario, feed costs as a proportion of total cow/calf production costs were low and there was little difference between treatments in their total value. However, with a HFC scenario not only did total production cost increase but so too did feed as a proportion of it. The economic benefits gained by VEW and EW under a HFC scenario increased. As determined by previous researchers (Story et al. 2000; Julien and Tess 2002) and confirmed in this study, capturing the full economic benefits of earlier weaning requires retained ownership to slaughter as part of the total management plan.

In both the LFC and HFC scenarios VEWF and EWF increased both the total feed and yardage costs as compared to VEWP, EWP and NW treatments. Likewise, performance of the VEW calves immediately postweaning was impaired relative to EW and NW treatments. Factoring together the variables of feed and yardage and animal performance it would be best if the calves were EW and backgrounded on pasture, than in confinement where there would be additional costs coupled with a rate of gain not justified within a feedlot confined feeding situation. Likewise, if calves are to be backgrounded during the winter months under a HFC scenario, lower rates of gain would make the cost of gain that much greater. If calves are retained under a HFC scenario this can have a severe negative impact because of the cost of gain increase and the reduced value at sale because of continued high feed costs.

The results of the HFC scenarios mirror quite closely the results of the 2002 drought on western Canada. In contrast, the surplus of feeds and pasture resources in 2005 is having a similar effect to a LFC scenario. Understanding how weaning will biologically impact the cow/calf enterprise is important, however, more important is understanding how costs of production can change and understanding how weaning can shift costs from one enterprise to another.

The cow/calf industry is different from the pork and poultry industries, primarily because there are many environmental parameters that cannot be controlled. These environmental variables, along with nutritional swings in forage quality, will always make the decision of when to wean one that will have to be based upon the variables at hand rather than weaning being set at the same time every year.

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CHAPTER 7

CHANGING WEANING DATES AS A PRACTICAL BEEF MANAGEMENT TOOL AND FUTURE RESEARCH

7.1 Introduction

The amount of harvested and purchased feed required to sustain a cow herd is highly correlated with the cost of production of the cow/calf enterprise (Kaliel, 2004). Influencing the costs of production will be the calving and weaning dates. By changing the calving and/or weaning date, cow/calf enterprises can better match the nutrient requirements (CP and TDN) of the cow with the nutrient quality of available forages. This will result in more efficient utilization of the ranch resources with minimal risk of jeopardizing cow body condition and reproductive performance.

The results in Chapter 3 showed that weaning is a highly effective tool for managing cow body condition and body weight in spring calving beef herds. Changing the weaning date can be used to extend the grazing resource, reduce the amount of winter feed needed and influence the economic returns to cow/calf enterprises.

Holding back weaning management as a practical beef management tool is the question, "How can it be practically implemented by the cow/calf industry?"

7.2 Management of the very early and early weaned calf until the time of normal weaning

Before weaning time is considered, it is important to evaluate the age of the calf. The age at which calves are weaned will have an important influence in determining both the nutritional (CP and TDN) needs and the practical management aspects (feedlot backgrounded vs. pasture backgrounded) of the calf.

As described in Chapter 2, a nursing beef calf does not become a fully functioning ruminant until 70-90 days of age. The decision to very early wean (VEW) calves (<92 d of age) should only be made under situations of severe drought coupled with very poorly conditioned (BCS≤1.5; BCS 1= emaciated and 5=grossly obese) cows that would have reduced conception rates should they continue to lactate during the breeding period. If calves are VEW (<90 d) it is best to first introduce new feeds in a creep feeder before weaning so that the naiveté of the calves to the new feed source is reduced. Once calves have become accustomed to the new feed source it is possible to remove them from their dams. In this study (Chapter 3) not only did VEW calves have reduced live weight gains compared to unweaned calves but there were also differences between whether they were backgrounded on pasture or in the feedlot. If the desire is to keep gains of the calf as close to those that would be achieved while nursing the cow, the best backgrounding system would be within a feedlot/ confined feeding system.

The diet for VEW calves (<90 d of age) should be highly palatable, high in available energy, vitamins and minerals to make up for reduced dry matter intakes immediately post weaning. In this study a dairy calf starter that had 22% CP and an 84% TDN value was used as a creep feed while the calves were nursing and during the initial stages after weaning. After weaning and once intake of the dairy calf starter is greater than 2.5 kg / day, the switch to a less expensive feed source like oat grain and high quality alfalfa/brome hay can be made. It is important that the ration not be limitfed and there is good access at all times.

Early weaning (EW; >132d) will be much easier for cow/calf enterprises to implement than very early weaning. Not only is the rumen more developed but the naiveté of the calf to new feeds is reduced because of its decreased dependency on milk from the dam (Green and Buric 1953). At four to five months of age the calf's digestive system is also more developed, allowing greater flexibility in nutritional and physical management of the calf.

The physical handling of VEW and EW calves both pre and post weaning will also play an important role in how well calves perform. All the calves in this experiment were vaccinated preweaning with a modified live vaccine for IBR, BVD, BRSV and Pasturella. This helped to minimize any risks associated with these diseases. However, more important than vaccinating the calves preweaning is minimizing the stress level of the calf. Minimizing weaning related stress is important no matter what age the calf is at weaning.

In this study calves that were both VEW and EW were first held in smaller pens so as to reduce fence line pacing and so that calves could quickly find feed and water. The pens were also walked by pen checkers three times per day to settle the calves and to get them to drink and feed. After 10 days, and once they were judged to be properly eating and drinking they could be moved into a larger feeding pen or back to pasture.

Economically the pasture backgrounding system is a lower cost alternative compared to the feedlot backgrounding system (see Chapter 5). Although feed costs can account for some of the economic differences between the two backgrounding systems, the main difference would be the higher cost of yardage associated with the feedlot backgrounding system. Evaluated from a biological perspective, the feedlot backgrounding system resulted in better live weight gains for both the VEW and EW treatments than the pasture backgrounding system. Cow/calf producers deciding which system to use would have to make a comparative economic analysis between the two and decide which system best fits their needs and is suited to their financial situation. In this study, although pasture backgrounded heifers and steers had reduced body weight gains as compared to feedlot backgrounded calves, their cost of gain was lower (Chapter 5).

7.3 Finishing and backgrounding of the very early and early weaned calf

Overall, results of this study indicated that feedlot ADG of the VEW and EW steer calves are equal to those of the normal weaned (NW) steers. The one negative aspect of the VEW calf was the reduced gains for the first 60 days immediately post weaning. Because all treatments were fed for the same length of time, live finished and carcass weight for the VEW steers were less than those of the EW and NW steers. If VEW calves are to be fed to finish, extra days on the finishing ration would be needed if the goal is to have similar weights to those of the EW and NW calves.

As for carcass qualities all weaning treatments had similar values. In this experiment a two implant program was used to maximize gain, feed conversion and reduce yield grade issues. An aggressive implant program in this study was used to minimize poor yield grade issues.

In this study the backgrounding of VEW heifers at a rate of gain <0.75 kg/d prevented compensatory gain during backgrounding. If the management desire is to have VEW calves at a similar weight to NW calves at the time of normal weaning then the energy value of the ration needs to be increased so that there can be compensatory gain.

VEW and EW heifer calves can have reduced cyclicity as compared to NW heifer calves. The impact if heifers are to be retained as replacements can be economically significant because it will reduce pregnancy rates. However from a practical standpoint, by breeding heifers for a short 42-d period, cow/calf producers can use this to their advantage by selecting for the most fertile heifers and culling the sub fertile heifers and finishing them while they are still under 30 months of age. If the goal is for maximum conception during the breeding season then heifers need to be fed so that their live weight-for-age is correct (Gordon 1993).

7.4 Very early and early weaning and the implications on cow herd productivity

This study shows that VEW and EW of spring calving cows over a three year period results in cows that have greater BW and BCS than cows that are NW. This BW and BC could then be used to feed cows with less feed over the winter months. Body weight and BCS changes are also cyclical in nature and cows in all treatments lost and gained BW and BCS over the course of the year. Many researchers (Whitman 1975; Deziuk and Bellows 1983) have indicated that VEW prior to the breeding season can result in improved conception rates as compared to later weaned treatments. However, authors Whitman (1975) and Deziuk and Bellows (1983) also concluded that the improvements in conception from early weaning are greatest in first and second calving cows that have a BCS of less than <2.0 BCS (scale 1-5) at calving. Cows in this study always maintained BCS >2.5 at calving and were not first and second calving cows. So there were no improvements in conception rates by VEW or EW as compared to NW.

After taking into account cows culled for low BCS, poor feet, poor udder scores and/or calf death loss or late abortions, NW and EW cows had higher culling rates than VEW cows (46% and 42.3% vs. 33.3% respectively after three years). Although there were no differences in pregnancy rates, VEW may decrease the probability of cows being culled for things other than being open. For some cow/calf operations this may be an important consideration, especially if there is a desire to minimize the number of replacement heifers kept for the herd.

7.5 Very early and early weaning and the implications on the production costs

In evaluating the differences in the production costs between the VEW, EW and NW cows assumptions were made from previous work modeled on the grazing and winter feeding costs of cows (Koberstein et al. 2001; Landblom et al. 2005). The AUM value and cost was adjusted for a weaned cow as compared to an unweaned cow and winter feed needs were adjusted to reflect the BCS differences among treatments (Koberstein et al. 2001; Landblom et al. 2005). Differences in grazing and winter feeding costs among treatments resulted in the VEW cows having the lowest production cost, EW intermediate and NW cows having the highest production costs. Should grazing and feed cost be impacted by drought, the production cost differences between treatments would have been even greater (Chapter 6). Every cow/calf enterprise has a different set of circumstances and production cost parameters; it is therefore important that cow/calf managers realize these costs and calculate them accordingly for their own particular operation.

Selling calves at the time of weaning would have resulted in a negative return to the cow/calf enterprise for both VEW and EW. Even though these two weaning treatments have lower production costs than NW cows, there is not enough income generated from the sale of lighter weaned calves to cover the cow/calf production expenses. To fully capture the potential from VEW or EW, retained ownership until slaughter should be considered. Evaluated economically as an entire system, in which ownership of steer calves were retained through the feedlot and replacement heifers were backgrounded and then sold, the combination of EW cows and pasture backgrounding steers and heifers until normal weaning resulted in the greatest revenue generated per cow as compared to VEW and NW.

7.6 Improvements that can be made in future research

A large part of the work studying rumen development in calves was done from the early 50s to the mid 70s. Rumen inoculation and nutritional requirements for CP and TDN for VEW calves to support growth similar to unweaned calves is an area future researchers should investigate. Coupled with the nutritional needs of young nursing calves, investigation into the role and/or the feed value of milk at different stages of lactation would also be warranted. Little information exists on this subject.

Improving BW and BCS and or feeding less to keep the same BW and BCS will be the most measurable benefit from a VEW or EW management system. Not only can VEW and EW change cow nutritional needs but it will extend available grazing resources and allow cow/calf producers more flexibility in winter feeding programs; both in terms of what is fed and how much of it is needed. Work by both Koberstein et al. (2001) and

Landblom et al. (2005) have helped to quantify the dollar value of BC and weaning on extending summer pasture and winter feeding resources.

In this study cows were originally assigned into three wintering groups, independent of weaning treatment: overfed (115% of recommended NRC: NE_M 0.98 Mcal/kg), normal fed (100% of recommended NRC: NE_M 0.85 Mcal/kg) and underfed (85% of recommended NRC: NE_M 0.72 Mcal/kg). The plan was to study the interaction between weaning treatment and winter energy intake, to determine whether earlier weaned (presumed fatter) cows would be less affected by low winter energy levels over the three-year period. Unfortunately, this part of the study was difficult to control. Weather patterns on the research station over the three winters were atypical and varied from excessive wind chill in some pastures to little or no snow in others. A lack of snow cover allowed some cows access to forage aftermath even in the middle of winter, making it impossible to control energy intakes. An example of this was that supposedly underfed cows (85% of recommended NRC) refused to eat their ration because they could continue to graze.

In addition there was excessive wind chill exposure (60 km / hr wind coupled with -35°C weather) in some of the pastures, which complicated energy balances to such an extent that the validity of the results were in doubt. Consequently, the results of the winter feeding portion of the study could not be used. Future work on weaning should look at feeding trials where the variables of weather and feed intake could be better controlled, so that better measurement of the value of BCS could be made.

Finally all future work should contain economic comparisons. Even though some research may show biological merit, it will not be adopted or used by the cow/calf sector if it does not reduce costs or increase returns.

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